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Effects of Seafood Waste Deposits on Water Quality and Benthos Akutan Harbor, Alaska

Jones and Stokes Associates, Inc.
Sacramento, CA

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This Environmental Assessment evaluates alternative methods of disposing of seafood processing wastes produced at Akutan Harbor, Alaska. It evaluates the impacts of these alternatives on water quality, harbor sediments, benthos, biology, beneficial uses of the harbor, the village of Akutan, and the seafood processing industry.

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Akutan Harbor, Alaska

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EFFECTS OF SEAFOOD WASTE DEPOSITS ON WATER QUALITY AND BENTHOS AKUTAN HARBOR, ALASKA

Prepared for:

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Work Assignment No. 9

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INTRODUCTION

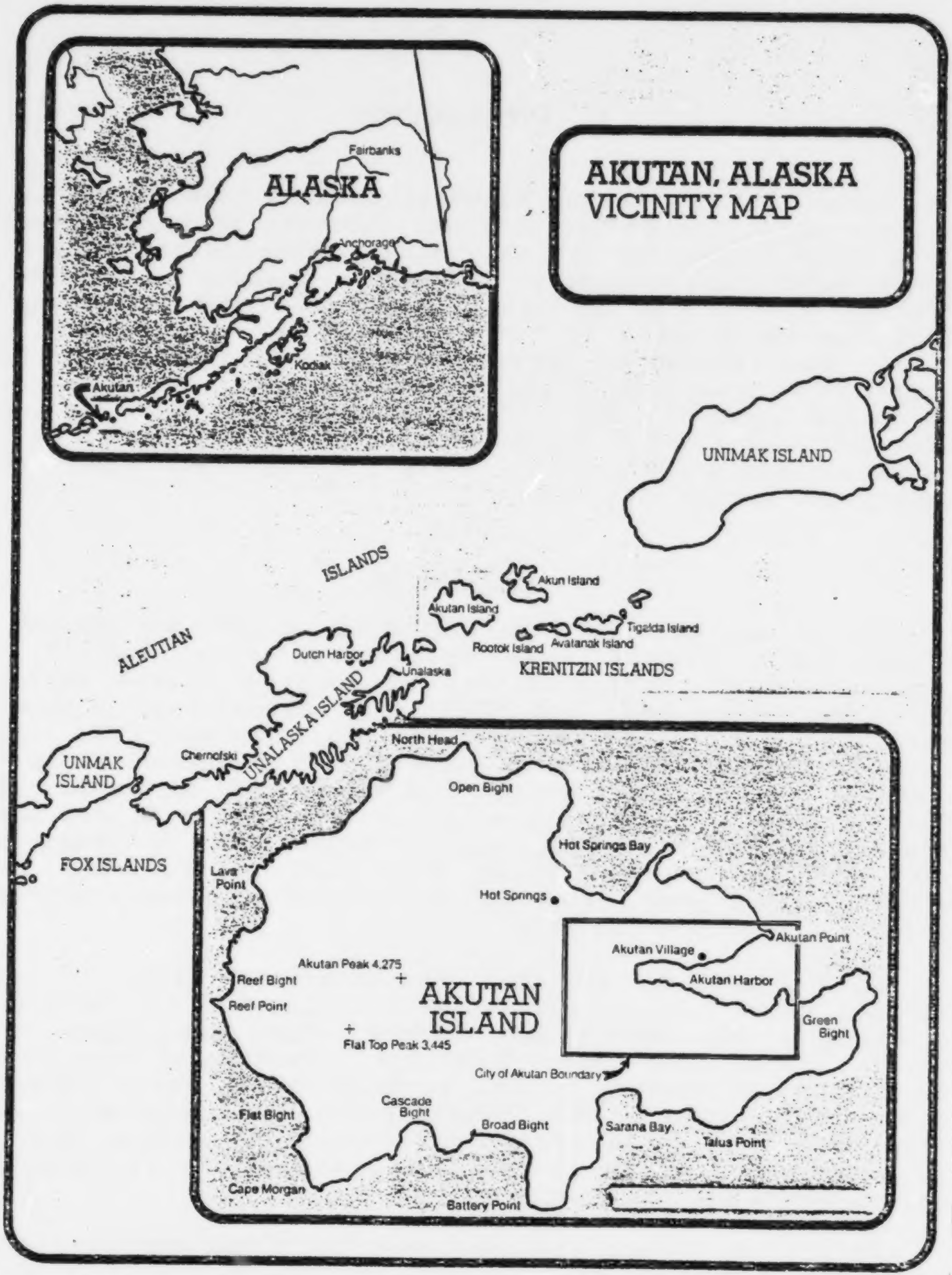
Akutan Island, in the Aleutian Islands (See Figure 1), has become a major center for seasonal floating seafood processors. A sheltered harbor on the east side of the island offers protected waters in proximity to vessels fishing in Bristol Bay crabbing areas. In addition, a major land-based processing plant was constructed by Trident Seafoods. The Trident plant has not been issued an NPDES waste discharge permit. Seafood wastes have been ground and discharged into the harbor since production began in May 1982. EPA issued a work assignment under Contract 68-01-6613 to obtain information needed to issue new or revised NPDES permits to the processors to protect water quality and harbor resources.

Objectives

Two water quality investigations of Akutan Harbor were carried out by Jones & Stokes Associates. From June 1-7, 1983, a crew of five representatives of Jones & Stokes Associates (including Tetra Tech and Williamson Associates, subcontractors), two EPA representatives, and one representative from the Alaska Department of Fish and Game (ADFG) conducted field work. A second field investigation was conducted September 15-21, 1983. A crew of four representatives of Jones & Stokes Associates (including Tetra Tech, subcontractor), one EPA representative, and one representative from ADFG participated in the September field work. Appendix A contains trip reports prepared by Jones & Stokes Associates.

The objectives of the investigations were: to assess existing water quality and sediment quality in the harbor, and to evaluate the impact of seafood waste discharges on the benthic biota. The major discharge investigated was from the new Trident processing plant, although other waste piles were located and sampled. The investigation was designed to obtain field data that would assist development of permit conditions and preparation of an environmental assessment on alternative seafood waste disposal methods.

Initially, it was intended that the water quality investigation would assess the impacts of the discharge plume and deposited solids on the receiving water. Major discharges, however, did not occur during the field work periods. Only two processors were active, and only crab was being processed. Data on discharges during codfish processing were not obtained. Trident Seafoods, Inc., was required to monitor receiving water quality and conduct dye studies as part of a Section 309 order (Clean Water Act). These data could have been used to evaluate


AKUTAN, ALASKA
VICINITY MAP
ALASKA
Fairbanks
Anchorage
Kodiak
Akutan
UNIMAK ISLAND
ISLANDS
ALEUTIAN
Akun Island
Akutan Island
Tigalda Island
Rootok Island
Avatanak Island
KRENITZIN ISLANDS
Dutch Harbor
Unalaska
UNALASKA ISLAND
UNMAK ISLAND
Chernofski
FOX ISLANDS
North Head
Open Bight
Hot Springs Bay
Lava Point
Hot Springs
Akutan Point
Akutan Village
Akutan Harbor
Akutan Peak 4,275
Reef Bight
Reef Point
AKUTAN ISLAND
Flat Top Peak 3,445
Green Bight
City of Akutan Boundary
Cascade Bight
Broad Bight
Sarana Bay
Talus Point
Flat Bight
Cape Morgan
Battery Point

SOURCE: CITY OF AKUTAN 1982.

FIGURE 1. GEOGRAPHIC LOCATION OF STUDY AREA.

water quality impacts from cod waste discharges; however, these data were not provided to EPA. This report, therefore, addresses the water quality impacts resulting from relatively low crab processing activity and from deposited seafood waste solids. Water quality impacts resulting from a higher volume discharge plume from the Trident plant are predicted based on an evaluation of hydrodynamic characteristics of the harbor.

Processing Activity

Conflicting data exist on the magnitude of recent processing activity in Akutan Harbor. According to the City of Akutan (1982), only one or two floating processors frequented Akutan Harbor prior to 1979. The M/V Akutan or the M/V Deep Sea would tie up at the village dock for seasonal fish and crab processing. In 1979, several additional floating processors anchored in the harbor. In 1980 and 1981, as many as 13 processors anchored in the harbor during crab season (City of Akutan 1982). Most of these processors move to other locations during other seasons. Data developed by ADFG indicate somewhat different estimates of the number of shellfish processors, but similar trends. Table 1 summarizes total shellfish processing activity, showing a peak in processing in 1980 followed by a sharp decline roughly paralleling the decline in Alaska crab catches. When crab are processed as sections, waste represents approximately 40 percent of body weight (Brown and Caldwell 1978).

Table 1. Shellfish Production[1] in Akutan Harbor

	1978	1979	1980	1981	1982
wt (10^6 lbs)	27.7	38.231	58.859	37.047	13.288
# Processors	7	7	11	8	4

---

[1] Finfish production data not available from ADFG

SOURCE: ADFG production statistics (Sundberg pers. comm.)

In 1982, a new land-based seafood processing plant, constructed by Trident Seafoods, began operation on the Island (Plates 1 and 2). A maximum seafood processing capacity of 600,000 pounds per day is provided by the plant. Products are mainly salted split cod and salted cod filets. Crab are brined, frozen, and packed as sections. Herring, salmon, and other species of bottomfish and shellfish are also processed, but in smaller quantities. The processing capacity for these additional species is not known.

The plant had processed approximately 9.1 million pounds of finished codfish products and 1.4 million pounds of other finished seafood products as of March 1983 (Soderlund pers. comm., Trident Seafoods pers. comm.). This resulted in a waste discharge of approximately 19.5-24.5 million pounds, based on a final product recovery equal to approximately 30-35 percent of raw weight (Evans Research Group 1983; Soderlund pers. comm.).

Processing of the Trident shore-based facility ceased, at least temporarily, on June 9, 1983 when fire destroyed the processing plant.

METHODS

This chapter describes the field methods used on June 3-6 and September 16-20, 1983.

Hydrodynamic Studies

Hydrodynamic studies conducted during the June survey consisted of observations of current-following drogues, tide measurements, and estimation of freshwater inflow.

"Window shade"-type drogues, constructed of mylar sheets one meter square, were used for current studies. The drogues were attached to surface floats by 6-mm diameter floating line. The use of floating line reduced the buoyancy and size requirement of the surface float. Fishnet floats which had a projected area of approximately 103 cm^2 were used in June. With the float nearly half submerged, the projected area of the float in water was about 52 cm^2. This provided a projected area ratio of the drogue:float combination of 200:1. Positions of the drogue buoys were determined by a Motorola Mini Ranger Mark III electronic positioning system.

Measurements of tidal elevation were made with a Fisher Porter water level recorder. The recorder tracked the elevation of a float within a stilling well and recorded a value on punched paper tape every 6 minutes. The datum or reference level for the observations was arbitrarily established because of the lack of a vertical survey control point in the vicinity of the tide recorder. A continuous record was obtained from June 4-8, 1983.

Fresh water inflow from the largest stream was gaged in June using a pygmy current meter. Other streams were visually estimated by two observers.

The same "window shade" - type drogues were used during the September survey. Divers flags and floats were used instead of the fishnet floats to achieve a smaller area projected above the water. Drogue studies in September were designed to identify water movement between the inner and outer harbor, and the outer harbor and Akutan Bay. No tidal elevation or stream discharge measurements were made during the September survey.

Water Quality

Water in Akutan Harbor was sampled and analyzed to characterize the quality of receiving water and assist in evaluating impacts from seafood waste piles. Significant discharges did not occur during 1983 field work; Trident discharged crab wastes once during June fieldwork (Plate 3). Water quality conditions during substantial effluent discharges were not examined. These data were to be provided to EPA by Trident Seafoods, Inc. in compliance with a Section 309 (Clean Water Act) order.

Water quality parameters measured during June in the field included: temperature and turbidity as a function of depth, Secchi disk transparency, dissolved oxygen, color, and settleable solids. Laboratory analyses included: salinity; dissolved nitrate, nitrite, ammonia, and total Kjeldahl nitrogen; oil and grease; hydrogen sulfide; and TOC.

June water samples were collected at 10 stations with a Scott-Richardson bottle. One 500-ml subsample was fixed with 2 ml of zinc acetate for hydrogen sulfide analysis. Samples were preserved, and stored in ice for later laboratory analysis at Anchorage. Standard laboratory analyses were used in the parameter determinations. Water samples were delivered by field personnel to the analytical laboratory in Anchorage. Samples remained in custody of field personnel except during transit between airports.

June temperatures were measured using an InterOcean 513D electronic water quality probe. The dissolved oxygen and salinity monitoring features of this sensor were not functional during the June survey. Temperature was recorded at June sediment stations at the standard National Ocean Survey depths of surface, 2 m (6.6 ft), 5 m (16.4 ft), 10 m (32.8 ft), 15 m (49.2 ft), 25 m (82 ft), 30 m (98.4 ft), and bottom.

Secchi disk transparency was measured at selected sediment stations in June using a standard 20-cm diameter Secchi disk.

Turbidity measurements were made in June using a Hach turbidity meter (Model 106900-00) at each water quality station at depths of 0.9 m (3 ft), 15.2 m (50 ft), 21.3 m (70 ft), and near bottom. Dissolved oxygen was measured from near bottom samples at selected water quality stations by means of a titration procedure based on the Winkler method. Color was determined by comparison with precalibrated standards to yield platinum/cobalt units (PCUs). Settleable solids were measured using a 1-liter Imhoff cone.

Dissolved oxygen concentration, conductivity (salinity), pH, and temperature were measured in the field at 20 stations in September with a Martek Mark VIII water quality data logger. Water samples were taken at surface and near bottom with a Van Dorn water bottle. Dissolved oxygen concentration was also measured in September by Winkler titration of a subsample of surface water at each station. Turbidity measurements were made in September using a Hach turbidity meter (Model 106900-00) and subsamples of surface and near bottom water at each water quality station. A standard 20-cm Secchi disc was also used to determine water transparency at each station.

Sediment Studies

Sediments were sampled in Akutan Harbor in June and September to determine the magnitude and extent of substrate modifications and any associated impacts on infaunal benthos associated with seafood processing wastes. Outer harbor sediments were sampled to provide documentation of the existing substrata and data on possible alternative disposal sites. A cooperative effort was also carried out in June to collect data for the U.S. Army Corps of Engineers (COE) at sites proposed for a small boat harbor. The latter information was provided separately as raw data to the COE and is not discussed further in this report.

Side-Scan Sonar Surveys

On June 4 and 5, 1983 a sub-bottom profiling (SBP) and side-scan sonar survey was conducted in Akutan Harbor. This work was performed using a Klein 3.5 kHz sub-bottom profiler, 100 kHz side-scan sonar, and high resolution 500 kHz side-scan sonar. Navigational control was maintained using a Motorola Mini Ranger III positioning system. The 3.5 kHz SBP is a down-looking acoustic device used to identify structure in the upper portions of the sediment column, and was used on this survey to determine the depth of waste piles associated with seafood processing activities in the harbor. The side-scan sonar systems were used to locate individual piles of processing waste for subsequent sampling, and to characterize sediment type as an indication of the energy of the bottom environment with inference to the strength of bottom currents and circulation.

Sediment Sampling Procedures

Sediments were sampled at 36 locations in June and six locations in September. In June, one sediment sample was collected at each station using a 0.1 m^2 Van Veen grab. Samples with insufficient grab penetration (<10 cm), evidence of leakage, or disturbed sediment-water interface were discarded. Subsamples (475 ml) in June were labelled, frozen, transported to an analytical lab in Anchorage, and analyzed for grain size and ammonia content. Coarse grain size was determined using sieves that allow separation of particles down to 0.063 mm in diameter. The procedure for ammonia determination was distillation with distillate analysis. All analytical procedures were standard EPA-certified techniques. Samples remained in custody of field personnel, except during transit between baggage facilities at Dutch Harbor and Anchorage airports. The June subsamples were later transported from Anchorage to a commercial laboratory in Seattle for total organic carbon (TOC) and further grain size analyses. TOC was determined using a combustion-infrared analyzer after acidification.

In September, six sediment stations were occupied. Three samples were taken at each inner harbor station, and five samples were taken at each outer harbor and Akutan Bay station. September subsamples were labelled, kept cold, and transported on ice to an analytical lab in Seattle. Samples remained in custody of field personnel, except during transit between baggage facilities at Dutch Harbor and Seattle airports. A subsample for sulfide analysis was fixed with a zinc acetate solution immediately upon subsampling. Laboratory analysis consisted of grain size, ammonia, Kjeldahl nitrogen, TOC, pH, and sulfide following the same procedures used in June. Kjeldahl nitrogen was determined using a digestion, distillation, and titration procedure yielding organic nitrogen data. A pH electrode was used to determine pH. The distillation procedure with iodinometric titration was used in sulfide analysis.

Biological Sampling

A 0.1-m^2 modified Van Veen grab was used to conduct a reconnaissance-level survey of the benthic communities in the harbor. Biological sampling was concurrent with sediment sampling in June and September, i.e., sediment samples from each benthic station underwent physical, chemical, and biological analyses.

On the first day of benthic sampling in June, 19 stations were selected to characterize the bottom community throughout the harbor and out to Akun Strait. On the second day, 18 stations were selected to characterize community structure on or at the margins of the Trident waste pile, on an old (approximately 5-year) waste pile off the Village of Akutan, and on a waste pile of unknown age in the inner harbor (opposite the whaling station).

As each sample was brought on deck, notes were taken as to sediment color, odor, and composition. A 0.75-liter subsample was taken and preserved for 24 hours in 10 percent buffered formalin containing rose bengal stain. A second (approximately 0.5-liter) subsample was taken for lab analyses of sediment grain size, total ammonia, and total organic carbon as discussed earlier. The remaining material was gently washed through a 5-mm mesh screen and macrofaunal organisms were preserved in 10 percent buffered formalin for 24 hours.

After preservation for 24 hours in formalin and rose bengal stain, the 1-liter subsample was gently washed through 2-mm and 1-mm mesh sieves. Organisms retained by the sieves were returned to 10 percent formalin until shipment from Dutch Harbor (at least 24 hours). Shipment was made in fresh water. All specimens were then stored in 70 percent isopropanol after 48 hours in fresh water.

Identical sampling and sieving procedures were employed in September. However, excess formalin was decanted from sample jars and 70 percent isopropanol was added prior to shipment from Dutch Harbor.

Laboratory analysis consisted of sorting and identification to the lowest possible taxonomic unit. Polychaetes were shipped to Dr. J. Kudenov (Univ. of Alaska, Anchorage) for identification.

Underwater Television Camera

An underwater television camera (Hydro Products, Inc.) and video recording system were deployed in Akutan Harbor in June and in September. Preliminary transects in June were run over the Trident waste pile and southward across the harbor. During the preliminary survey, a diode burned out in the power supply and resulted in a current overload in the camera unit. Field repairs were unsuccessful; subsequent diagnosis determined that the vidicom tube had also burned out. Unfortunately, the video recorder was not in use during preliminary transects.

In September, recordings were successfully made at the Trident outfall site, southward of Trident in the inner harbor, off the City of Akutan dock, and at outer harbor stations.

RESULTS

Hydrodynamic Studies

Harbor flushing characteristics are determined primarily by the shape of the embayment, tides, freshwater inflow, and wind forces.

Bathymetry

Akutan Harbor is a typical, glacier-formed, fjord-type embayment (Figure 2). The harbor is approximately 6.3 km (3.9 mi) long from a line south of Akutan Point to the head of the harbor. Slopes along the side and head of the harbor are very steep with water depths of 18 m (60 ft) reached within 146 m (480 ft) from shore. The harbor bottom is relatively flat and gradually deepens from the head at 27 m (90 ft) to the mouth at 61 m (200 ft).

Tides

The tidal amplitude at Akutan Harbor is relatively small with a range between mean higher high water and mean lower low water of 1.2 m (3.9 ft). The tide at Akutan is such that it is semidiurnal around the times the moon is on the equator, but becomes diurnal around the times of maximum north or south declination of the moon (NOS 1983). The maximum (spring) tidal prism is less than 5 percent of the mean harbor volume, which is typical of a deep fjord embayment.

Figure 3 compares the June 5 and 6, 1983 tide predicted for Akutan Harbor to the tide observed along the south shore near Miniranger Station B (Figure 2). Tidal amplitudes compare reasonably well; a maximum difference of about 0.12 m (0.4 ft) was observed. It should be noted, however, that the vertical datum for the observed tide is arbitrary, so that a precise comparison of predicted and observed amplitude is not possible. The time of high and low tide does not compare as well as amplitude. The observed tide is approximately 3.5 hours later than the predicted tide. The reason for this is not known.

Tidal elevations were not recorded during the September survey because tidal action is not a dominant harbor flushing mechanism.

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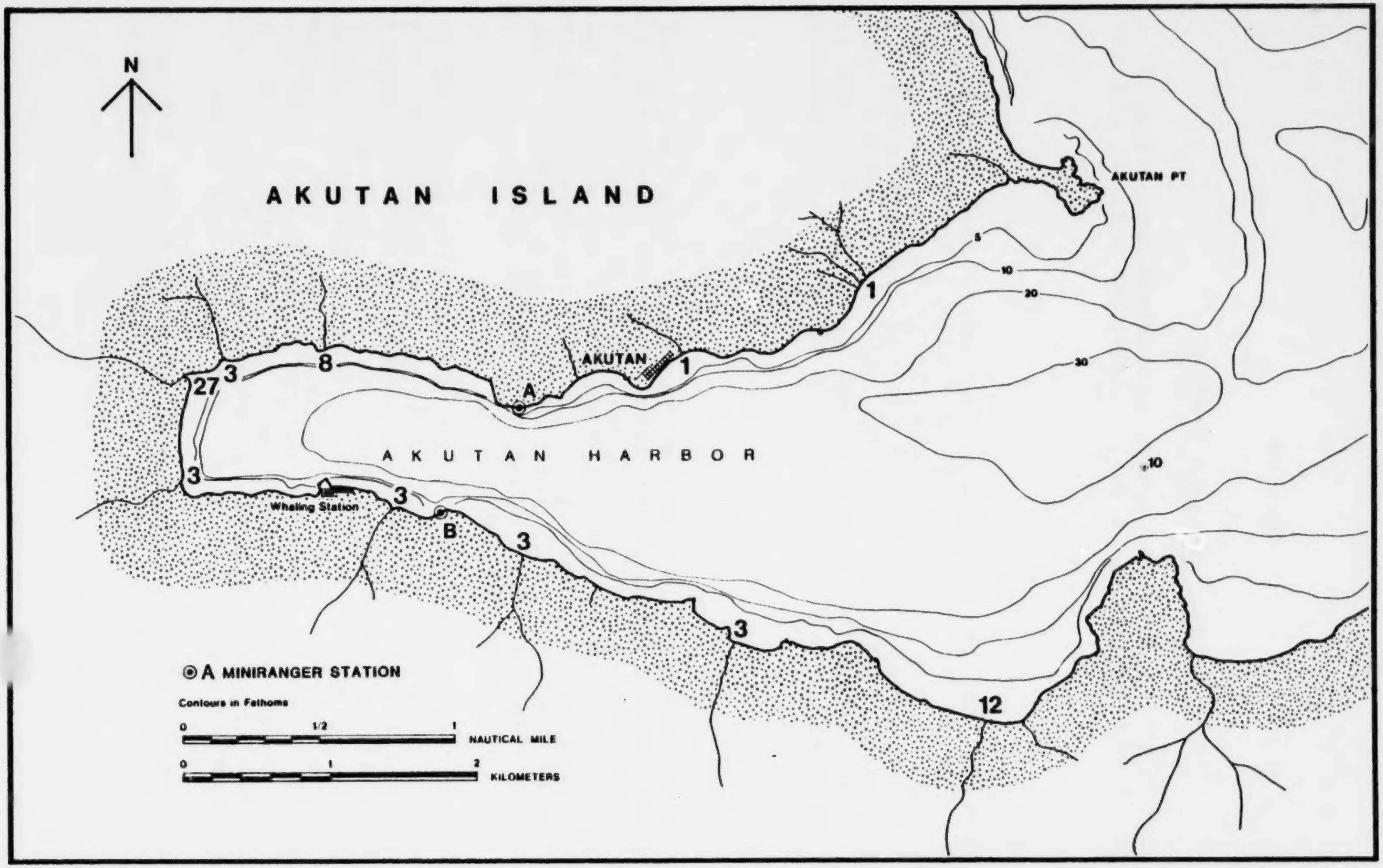

N
AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
A
B
27
3
8
1
1
3
3
3
3
12
5
10
20
30
10
A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 2. Estimated freshwater inflow to Akutan Harbor in cubic feet per second (cfs), on 5 June 1983.

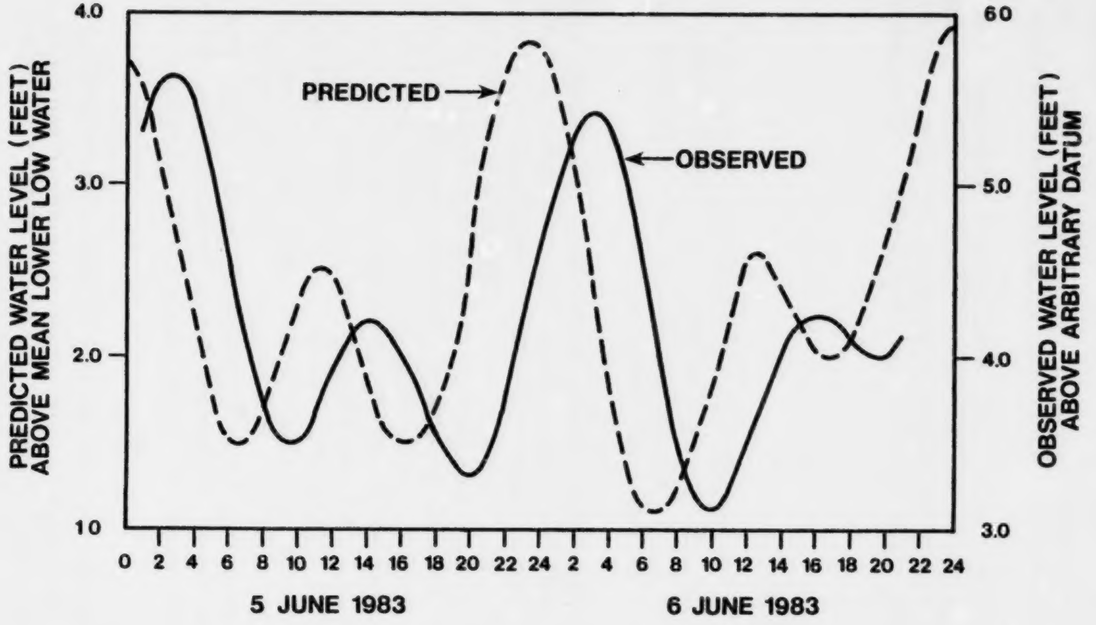


Figure 7. Comparison of predicted and observed tides, Akutan Harbor, 5 and 6 June 1983.

Freshwater Inflow

Estimated discharges of streams flowing into Akutan Harbor during the June survey are shown in Figure 2. The largest stream at the head of the harbor was gaged with a pygmy current meter. The discharge for all other streams was visually estimated by two observers. The freshwater discharge estimated during the June field survey was 1.8 m^3/sec (64 ft^3/sec). Over a tidal cycle, this is only about 0.01 percent of mean harbor volume.

Stream discharge was not estimated during the September survey. It is expected to be less than total stream discharge during the June survey because remnants of the winter snow pack were present in June but absent in September. Groundwater inflow is unknown.

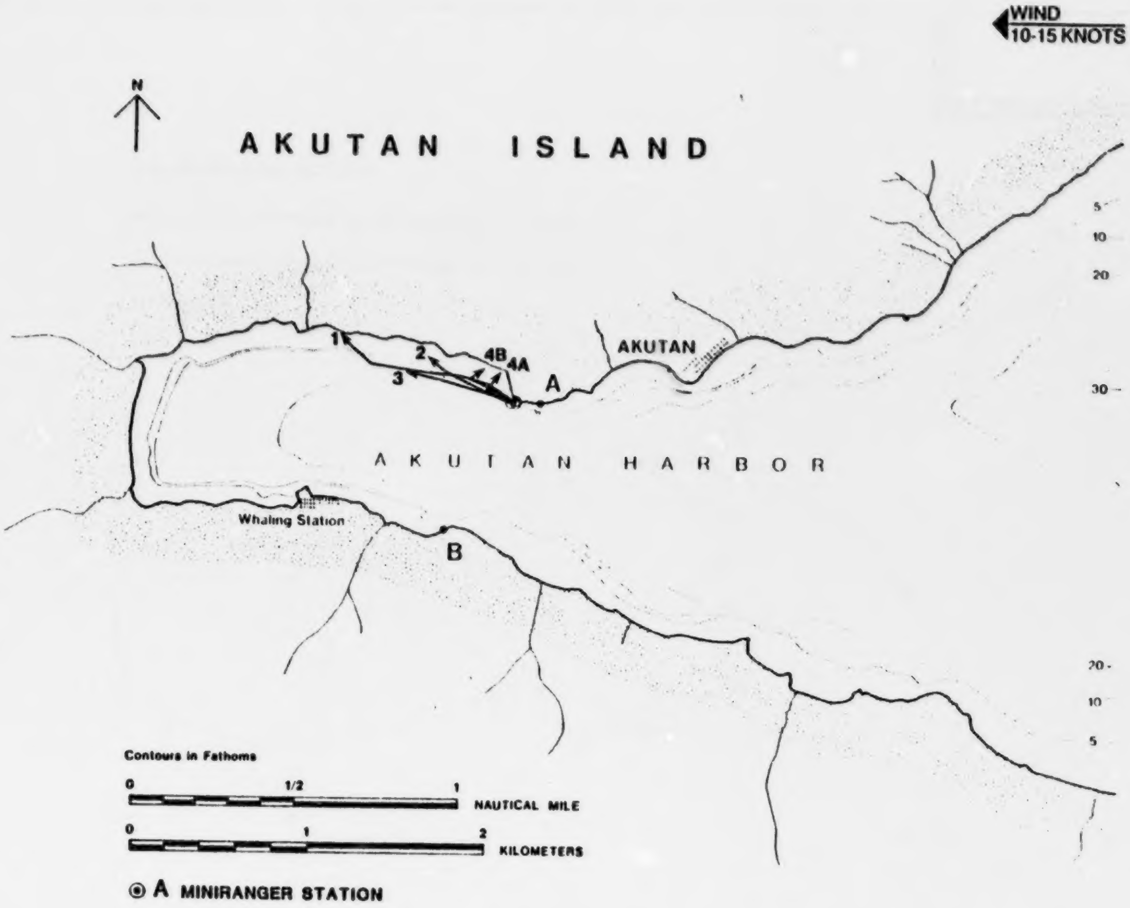
Wind-driven Circulation

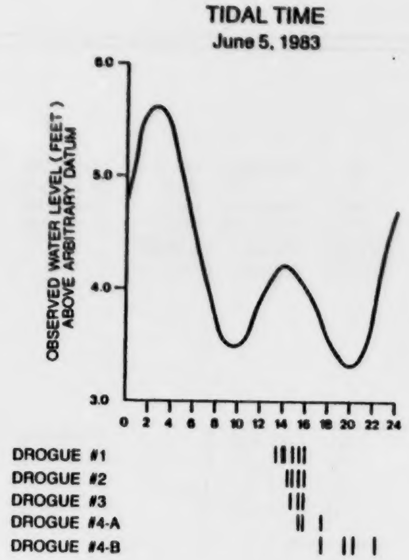
June data. To obtain an initial estimate of wind-driven circulation, drogue data collected in June 1983 have been analyzed and an analytical calculation of vertical and horizontal, circulation patterns has been made.

Drogue paths for June 1983 have been plotted and are shown in Figures 4, 5, and 6. Movement of surface drogues released nearshore in the vicinity of the seafood processing plant discharge is shown in Figure 4. Figure 5 depicts paths for drogues set at 15 m and released across an inner portion of the harbor. Figure 6 shows surface drogue paths along the outer boundary of the harbor. Over the 2-day field period, winds were consistently from the east at approximately 15 knots. According to the drogue data, an easterly wind sets up a relatively complex circulation pattern with surface currents directed inward toward the head of the harbor and deep currents directed outward through the harbor boundary. In addition, a counterclockwise circulation pattern exists in the outer portion of the harbor which may be wind related or a combination of wind-driven local currents and eddies from currents passing through Akun Strait.

To further characterize wind-driven circulation, an analytical solution to the governing fluid flow equation was solved for an idealized channel with a closed end following the method of Cooper and Pearce (1977) (Appendix B).

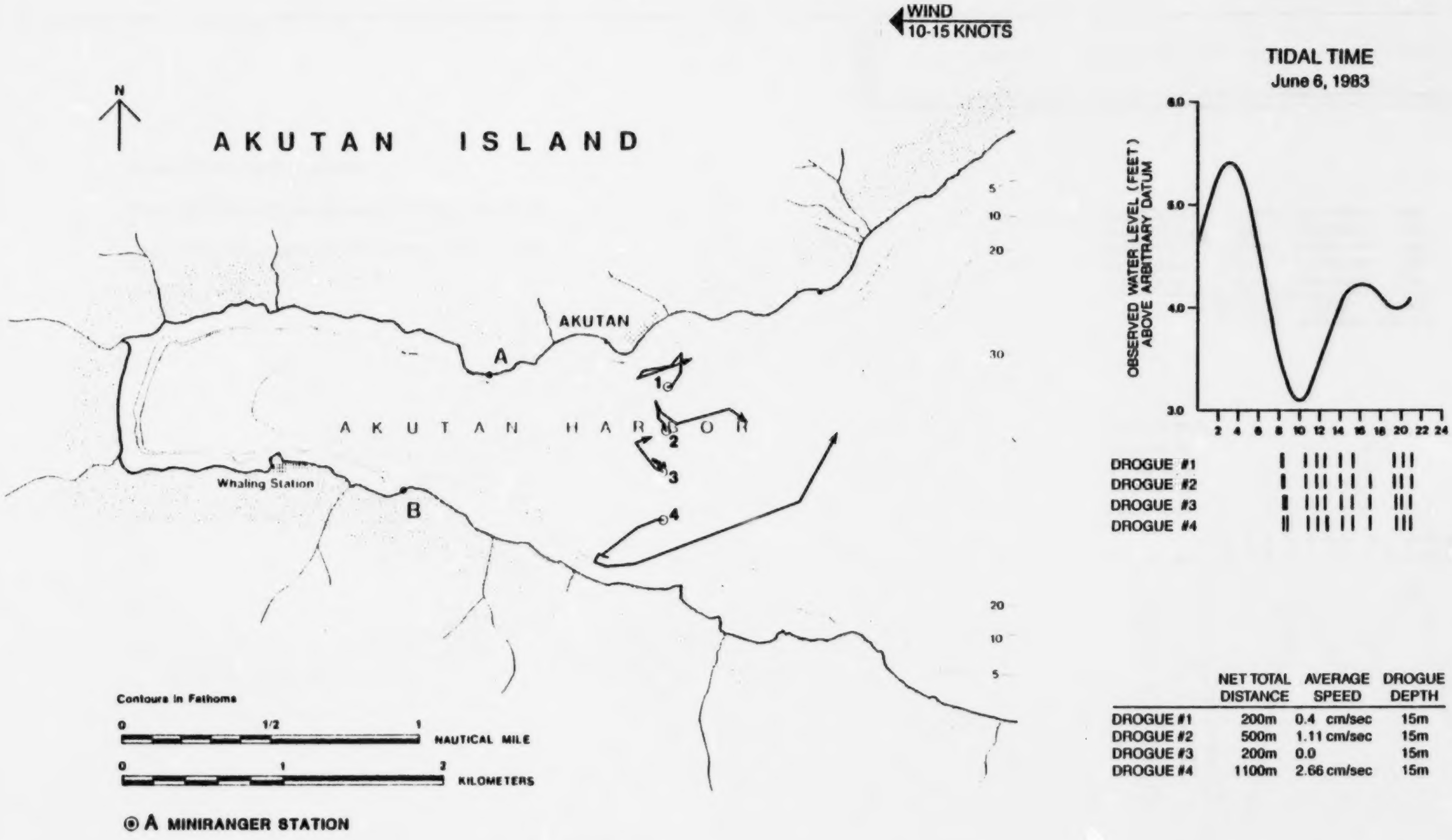
For Akutan Harbor, assuming a wind velocity of 15 knots from the east (steady state), a vertical eddy viscosity coefficient of 0.25 ft^2/sec (approximate value), and an average depth of 38.4 m (126 ft), the vertical velocity profile was computed as shown in Figure 7. Approximate net drogue velocities from the two inner harbor transects (Figures 4 and 5) are also shown for comparison to the analytical solution. Considering the simplified treatment of the analytical solution, the comparison between field drogue movements and the analytical solution is reasonable. Drogue velocities from the outer harbor


WIND
10-15 KNOTS
N
AKUTAN ISLAND
AKUTAN
1
2
3
4B
4A
A
B
AKUTAN HARBOR
Whaling Station
5
10
20
30
20
10
5
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
A MINIRANGER STATION



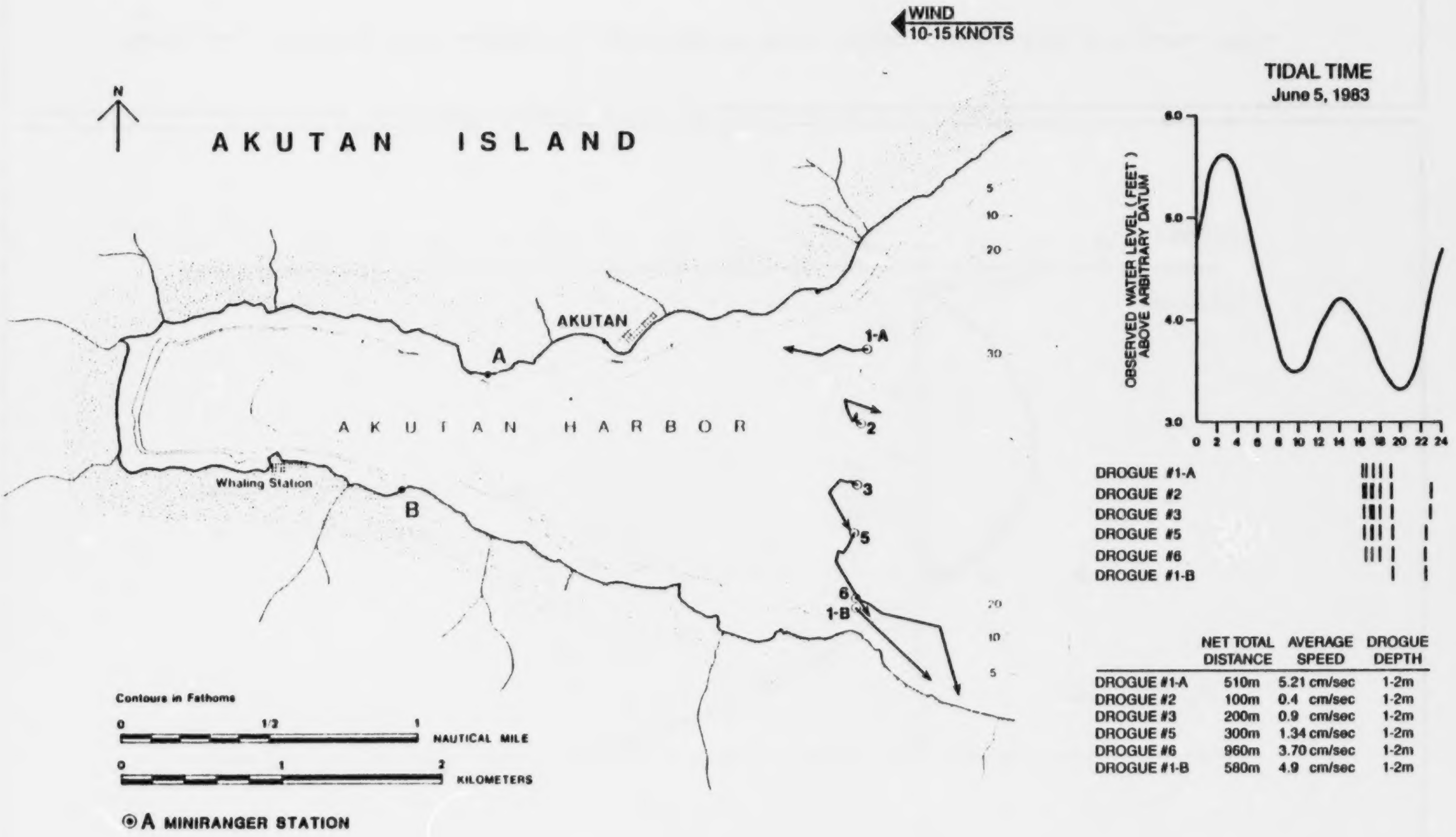
	NET TOTAL DISTANCE	AVERAGE SPEED	DROGUE DEPTH
DROGUE #1	850m	10.81 cm/sec	1-2m
DROGUE #2	500m	9.26 cm/sec	1-2m
DROGUE #3	580m	15.85 cm/sec	1-2m
DROGUE #4A	300m	3.97 cm/sec	10m
DROGUE #4B	370m	2.13 cm/sec	10m

Figure 4. Drogue positions - Outfall series. 5 June 1983.


WIND
10-15 KNOTS
N
AKUTAN ISLAND
AKUTAN
A
B
AKUTAN HARBOR
Whaling Station
1
2
3
4
5
10
20
30
20
10
5
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
⊙ A MINIRANGER STATION
TIDAL TIME
June 6, 1983
OBSERVED WATER LEVEL (FEET) ABOVE ARBITRARY DATUM
6.0
5.0
4.0
3.0
2
4
6
8
10
12
14
16
18
20
22
24
DROGUE #1
DROGUE #2
DROGUE #3
DROGUE #4

	NET TOTAL DISTANCE	AVERAGE SPEED	DROGUE DEPTH
DROGUE #1	200m	0.4 cm/sec	15m
DROGUE #2	500m	1.11 cm/sec	15m
DROGUE #3	200m	0.0	15m
DROGUE #4	1100m	2.66 cm/sec	15m

Figure 5. Drogue positions - 15 m depth. 6 June 1983.


WIND
10-15 KNOTS
N
AKUTAN ISLAND
AKUTAN
A
B
AKUTAN HARBOR
Whaling Station
1-A
2
3
5
6
1-B
5
10
20
30
20
10
5
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
⊙A MINIRANGER STATION
TIDAL TIME
June 5, 1983
OBSERVED WATER LEVEL (FEET)
ABOVE ARBITRARY DATUM
6.0
5.0
4.0
3.0
0
2
4
6
8
10
12
14
16
18
20
22
24
DROGUE #1-A
DROGUE #2
DROGUE #3
DROGUE #5
DROGUE #6
DROGUE #1-B

	NET TOTAL DISTANCE	AVERAGE SPEED	DROGUE DEPTH
DROGUE #1-A	510m	5.21 cm/sec	1-2m
DROGUE #2	100m	0.4 cm/sec	1-2m
DROGUE #3	200m	0.9 cm/sec	1-2m
DROGUE #5	300m	1.34 cm/sec	1-2m
DROGUE #6	960m	3.70 cm/sec	1-2m
DROGUE #1-B	580m	4.9 cm/sec	1-2m

Figure 6. Drogue Positions - 1-2 m depth. June 5, 1983

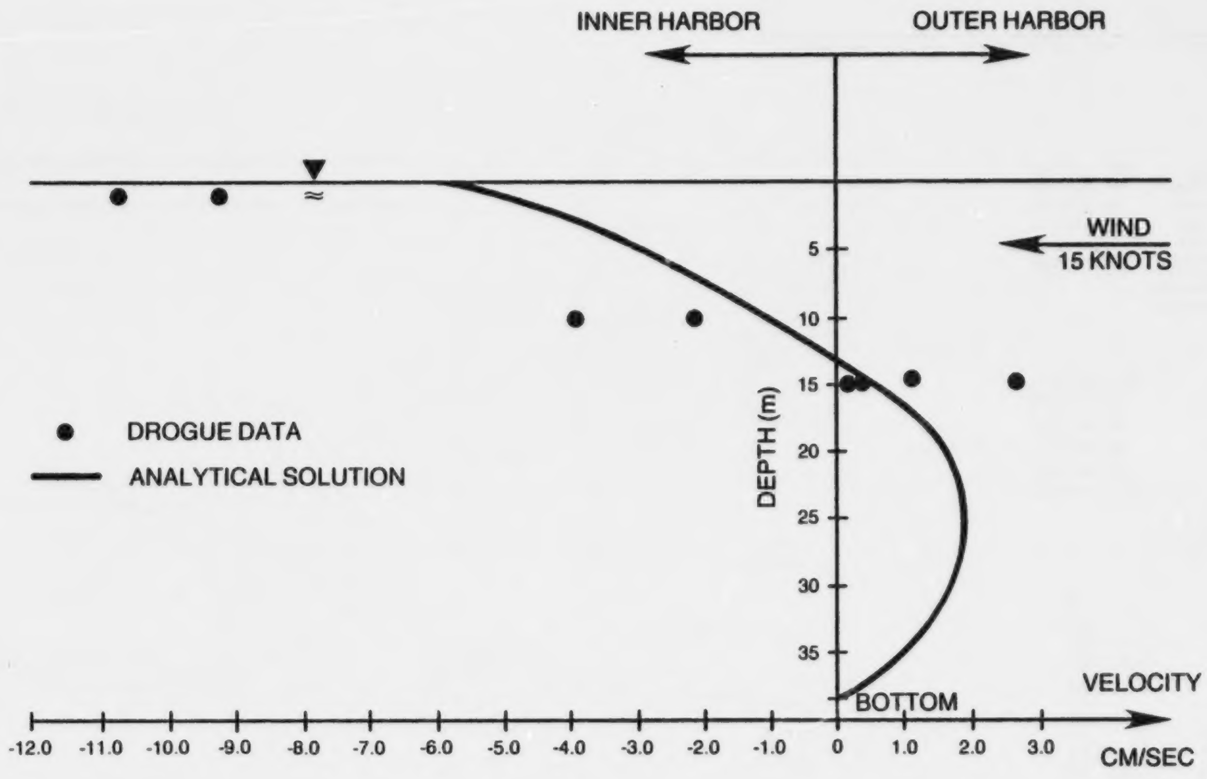


Figure 12. Comparison of analytical solution to inner harbor drogue data for June, 1983.

transect (Figure 6) were not plotted on Figure 7 since the drogues in this area indicated an apparent counterclockwise surface eddy, which is probably due to boundary effects and lateral eddies that the analytical solution cannot represent.

September Data. The movement of current-following drogues exhibited a complex pattern in September in response to variable winds. Winds on the day prior to drogue deployment (September 16) were light (about 5 knots) and from the east. During the early morning of September 17, winds from the east strengthened to a maximum of about 40 knots by 1300. Wind speed then decreased quickly to less than 5 knots by 1600. Winds remained calm on September 18 and 19 in rain and fog. Fog periodically hampered efforts to relocate the drogue surface floats.

The drogues set at 30 m (Figure 8) exhibited a generally counterclockwise circulation pattern in the outer harbor. During the nearly 48-hour period from about 1200 on September 17 to about 1100 on September 19 none of the 30-m drogues were advected out of the harbor. Minimum drogue velocities were generally less than 4 cm/sec. The largest 30-m drogue excursion was observed with drogue #15 along the southern side of the outer harbor.

The drogues set at 20 m (Figure 9) in the outer harbor moved out of the harbor from about 1600 on September 17 to about 1200 on September 18. Over the next 6-hour interval, the drogues moved southward. At the next observation, about 17 hours later, they had consistently moved back into the harbor. The minimum speed of 20-m drogues in the outer harbor during periods of less than 5 hours ranged from about 2.3 to 6.7 cm/sec.

The drogues set at 20 m in the inner harbor (Figure 9) traveled relatively small distances from 1200 on September 17 to about 1200 on September 18. Through the remaining time intervals, until 1100 on September 19, the inner harbor 20-m drogues moved outward along the south shore while the 20-m drogues in the outer harbor moved into the harbor.

The drogues set at 10 m (Figure 10) exhibited the largest excursions. From 1200 to 1600 on September 17, the 10-m drogues moved inward in response to the wind. By 2100 on September 17, the 10 m drogues moved outward with minimum velocities ranging from 7.2 to 9.9 cm/sec. At the next observation, around 1200 on September 18, the drogues had moved further east. Drogues observed in Akutan Bay were retrieved because it was assumed they would not return to the harbor. Two 10-m drogues moved back into the harbor between 1200 on September 18 and 1100 on September 19.

In summary, the drogues followed a complex pattern during the September survey. The patterns suggest that a counter-

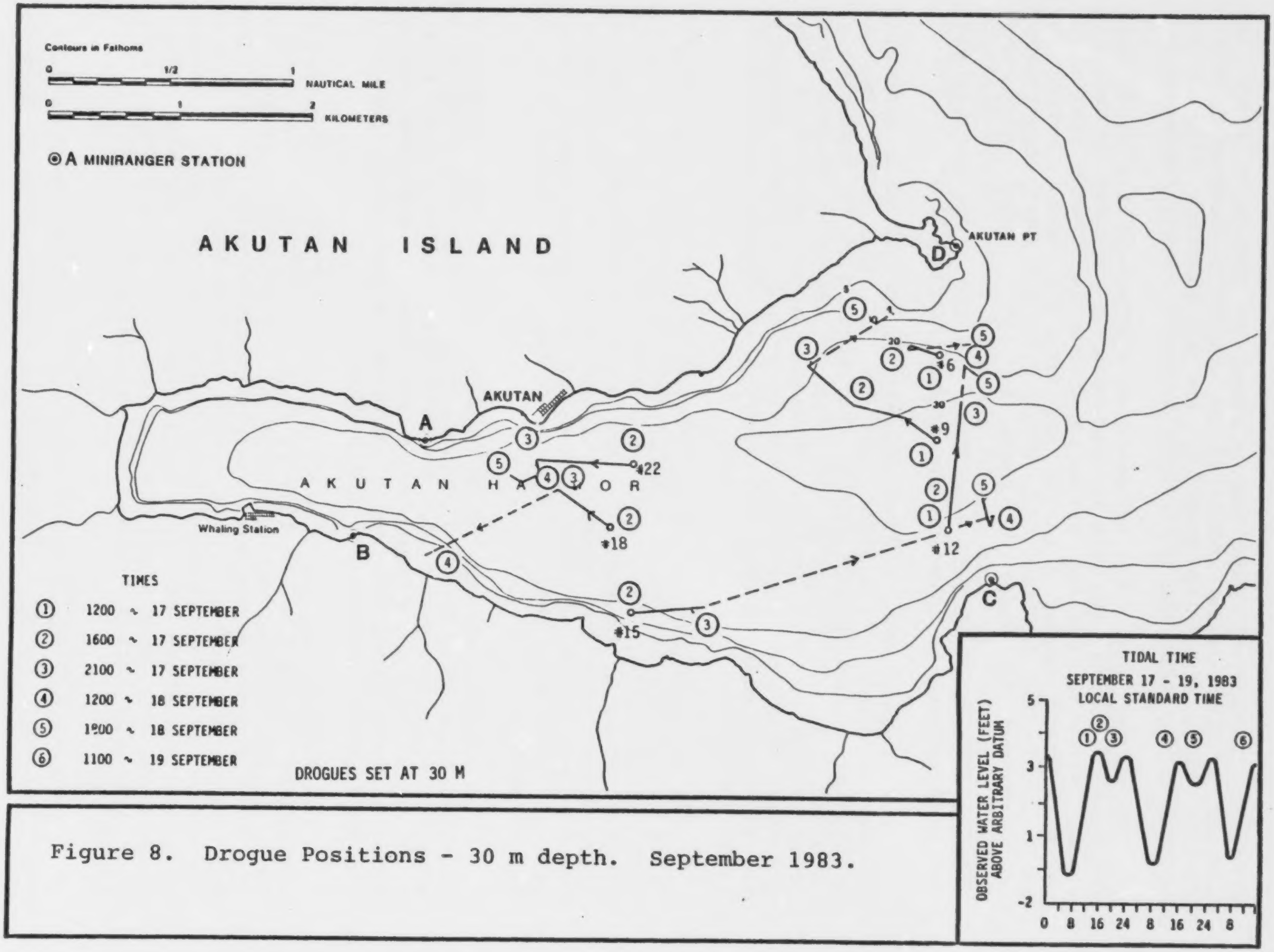

Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
⊙ A MINIRANGER STATION
AKUTAN ISLAND
AKUTAN PT
D
AKUTAN
A
B
C
Whaling Station
A K U T A N H A R B O R
#22
#18
#15
#12
#9
#6
30
20
10
5
TIMES
① 1200 ~ 17 SEPTEMBER
② 1600 ~ 17 SEPTEMBER
③ 2100 ~ 17 SEPTEMBER
④ 1200 ~ 18 SEPTEMBER
⑤ 1900 ~ 18 SEPTEMBER
⑥ 1100 ~ 19 SEPTEMBER
DROGUES SET AT 30 M
TIDAL TIME
SEPTEMBER 17 - 19, 1983
LOCAL STANDARD TIME
OBSERVED WATER LEVEL (FEET)
ABOVE ARBITRARY DATUM
5
3
1
-2
0
8
16
24
8
16
24
8
① ② ③ ④ ⑤ ⑥

Figure 8. Drogue Positions - 30 m depth. September 1983.

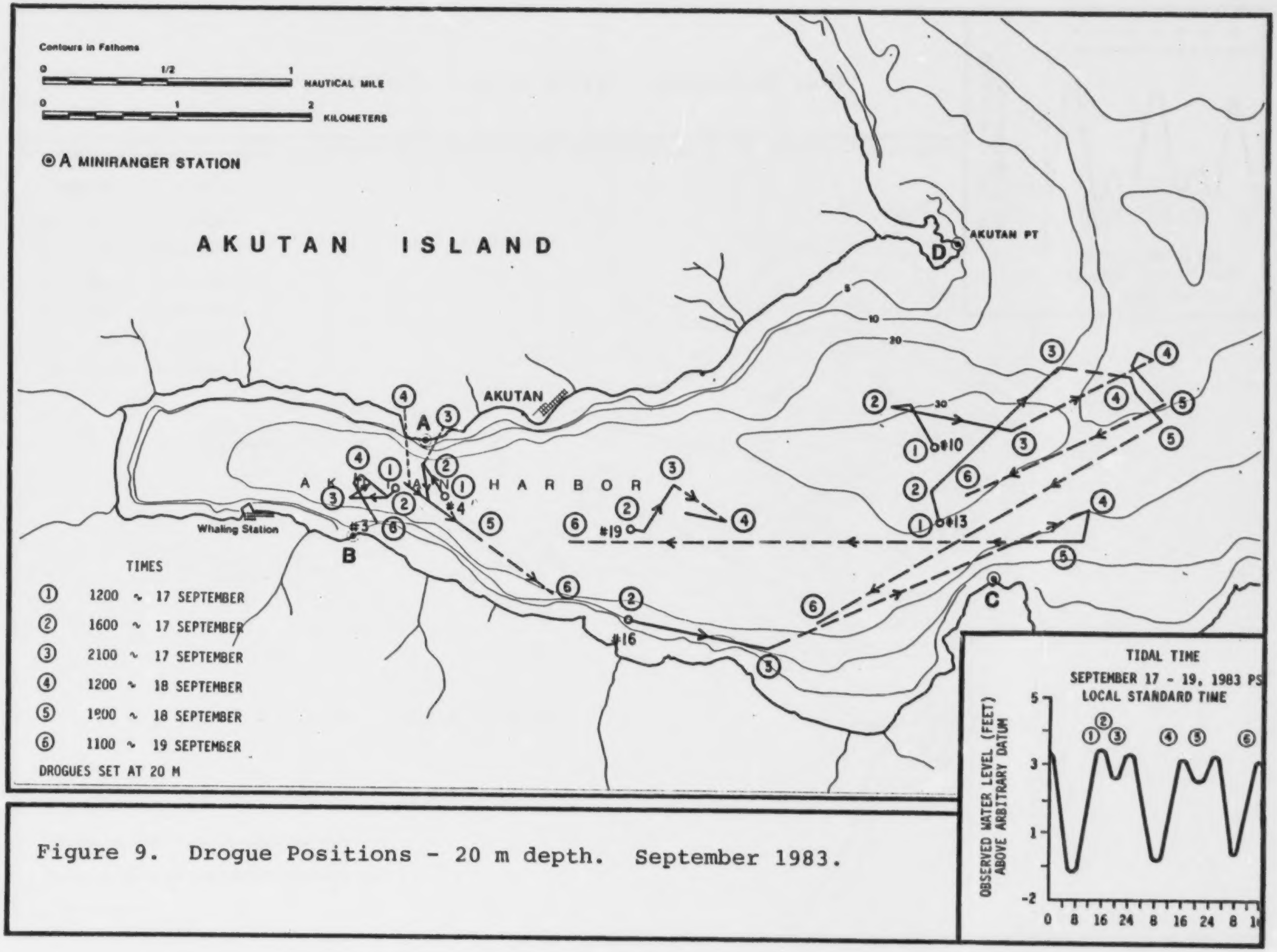

Contours in Fathoms
0 1/2 1 NAUTICAL MILE
0 1 2 KILOMETERS
⊙ A MINIRANGER STATION
AKUTAN ISLAND
AKUTAN PT
D
AKUTAN
A
B
C
AKUTAN HARBOR
Whaling Station
#3
#4
#10
#13
#16
#19
5
10
20
30
TIMES
① 1200 ~ 17 SEPTEMBER
② 1600 ~ 17 SEPTEMBER
③ 2100 ~ 17 SEPTEMBER
④ 1200 ~ 18 SEPTEMBER
⑤ 1900 ~ 18 SEPTEMBER
⑥ 1100 ~ 19 SEPTEMBER
DROGUES SET AT 20 M
TIDAL TIME
SEPTEMBER 17 - 19, 1983 PS
LOCAL STANDARD TIME
OBSERVED WATER LEVEL (FEET) ABOVE ARBITRARY DATUM
5
3
1
-2
0 8 16 24 8 16 24 8 1

Figure 9. Drogue Positions - 20 m depth. September 1983.

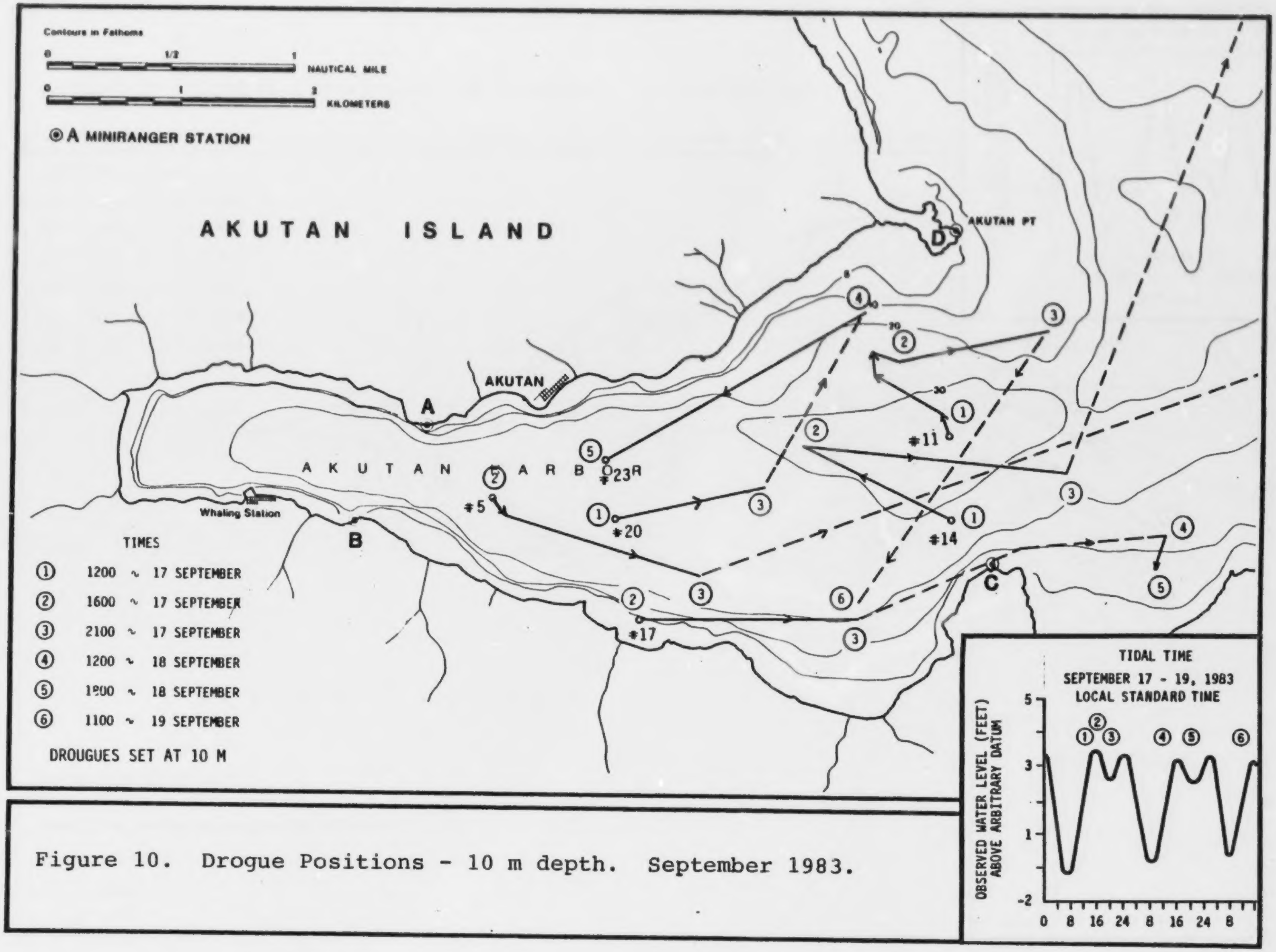

Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
⊙ A MINIRANGER STATION
AKUTAN ISLAND
AKUTAN
A
B
C
D
AKUTAN PT
Whaling Station
AKUTAN HARBOR
#5
#20
#23R
#17
#14
#11
30
TIMES
① 1200 ~ 17 SEPTEMBER
② 1600 ~ 17 SEPTEMBER
③ 2100 ~ 17 SEPTEMBER
④ 1200 ~ 18 SEPTEMBER
⑤ 1800 ~ 18 SEPTEMBER
⑥ 1100 ~ 19 SEPTEMBER
DROUGUES SET AT 10 M
TIDAL TIME
SEPTEMBER 17 - 19, 1983
LOCAL STANDARD TIME
OBSERVED WATER LEVEL (FEET) ABOVE ARBITRARY DATUM
5
3
1
-2
0
8
16
24
8
16
24
8

Figure 10. Drogue Positions - 10 m depth. September 1983.

clockwise circulation pattern was present in the outer harbor at 30 m. The drogues at 20 and 10 m moved in a direction out of the harbor following a decrease of strong winds from the east. The 20-m drogues subsequently moved back toward the harbor but some of the 10-m drogues presumably would not have returned.

A second, and perhaps more meaningful method to estimate flushing time is to examine the salinity distribution in Akutan Harbor through the "fraction of freshwater method" (Tetra Tech 1983). The equations used to develop this estimate are described in Appendix C. The technique subdivides the harbor into segments displaying uniform salinity throughout the segment. Salinity data collected in Akutan Harbor in September are presented in Appendix D. In general, these data indicated small salinity gradients in the horizontal and vertical directions, so selection of segment numbers and sizes was not critical to the flushing time calculations by the above method. As such, the harbor was divided into six segments (Figure 11). The resulting total flushing or residence time (Appendix C) is estimated to be approximately 177 days (342 tidal cycles). Note, however, that the flushing time calculation is very sensitive to total freshwater inflow (R), which was not actually measured for the September survey period. In fact, if the average residence time of Akutan Harbor is on the order of 177 days, then it is necessary to know the average freshwater inflow which occurred over a similar period of time prior to the September survey of salinity profiles. If the average total freshwater inflow was significantly greater than 64 cfs, then the estimated flushing time would be significantly less than given above. For example, for twice the freshwater flow used, the total flushing time would be halved.

Water Quality

June Data

In June, temperature and Secchi disc readings were taken at background sediment stations (Figure 12). All other water quality data were taken at 10 water quality stations (Figure 13). These data are summarized by station in Appendix E.

Temperature. Temperatures at various depths and water column transparency were determined at the same time and locations as Sediment Samples 1-19 (Figure 12). Sediment Station 19 was located at the north end of Akun Strait (Figure 12 inset). Table 2 summarizes temperatures recorded at depth. The temperature data show a slight decrease with depth, although the variation is not large enough to indicate even minor water column stratification. This mixed condition agrees with the earlier water quality studies conducted in May (EPA & ADEC 1978,

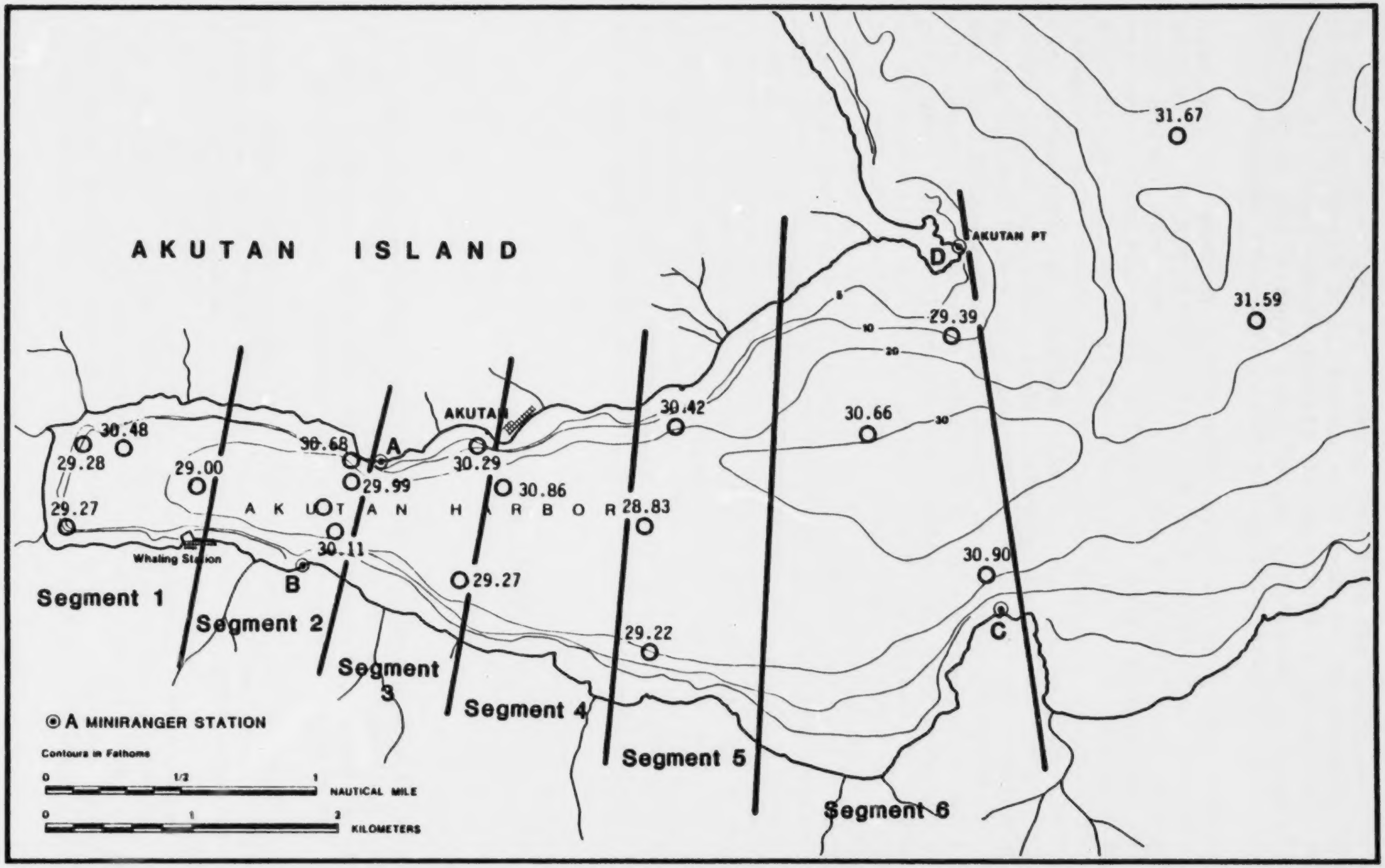

AKUTAN ISLAND
AKUTAN HARBOR
AKUTAN
AKUTAN PT
Whaling Station
A
B
C
D
30.48
29.28
29.27
29.00
30.68
29.99
30.11
30.29
30.86
29.27
28.83
29.22
30.42
30.66
29.39
30.90
31.67
31.59
8
10
20
30
Segment 1
Segment 2
Segment 3
Segment 4
Segment 5
Segment 6
⊙ A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 11. Depth - Averaged Salinity Distribution. September 1983.

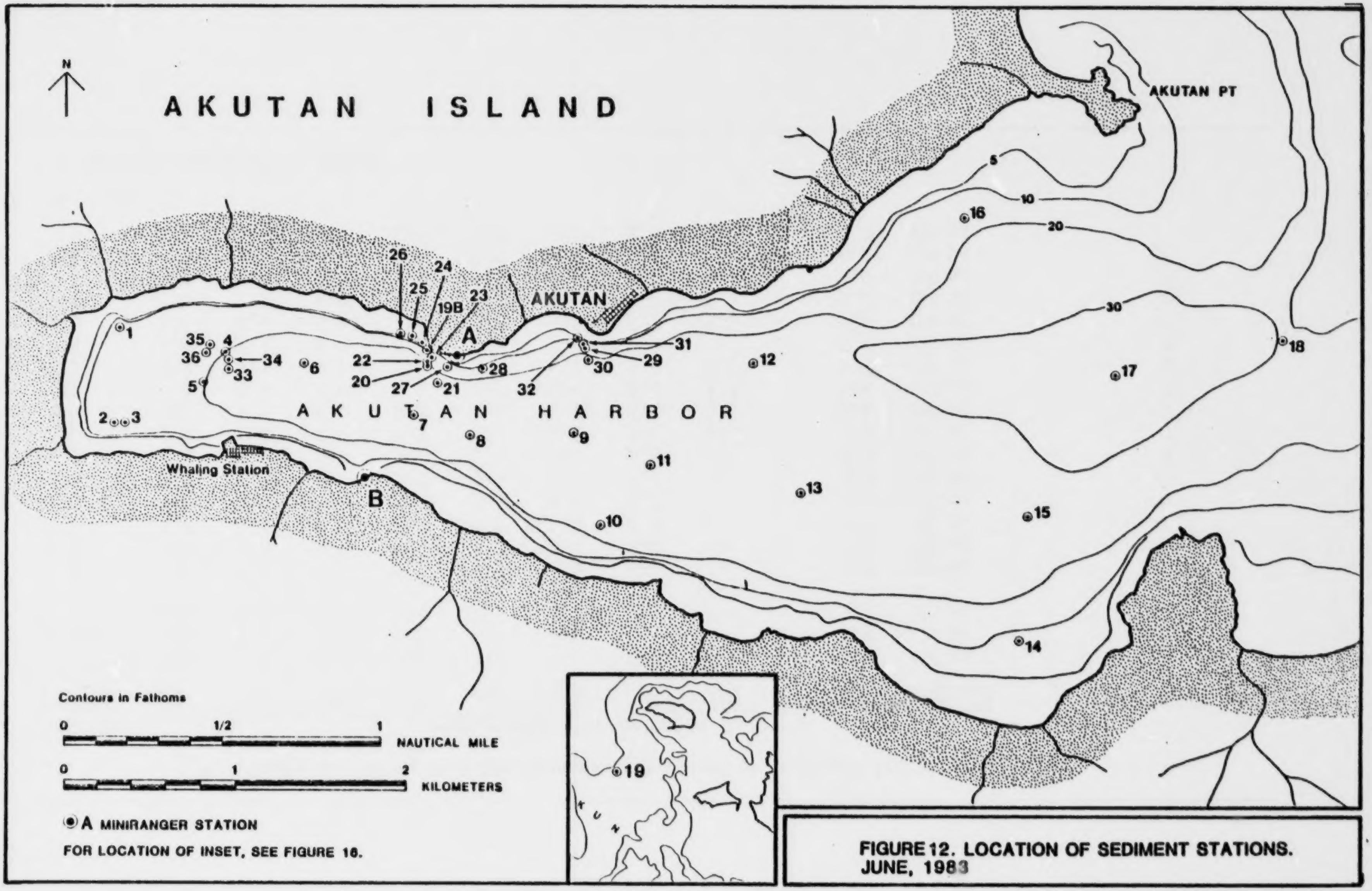

N
AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
A
B
5
10
20
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
19B
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
A MINIRANGER STATION
FOR LOCATION OF INSET, SEE FIGURE 16.

FIGURE 12. LOCATION OF SEDIMENT STATIONS.
JUNE, 1983

Table 2. Water Quality Parameters Measured at Sediment Stations in June

SEDIMENT STATION	TEMPERATURE (°C) AT DEPTH (m)										SECCHI DISK (m)
	0m	2m	5m	10m	15m	25m	30m	35m	NEAR BOTTOM	(DEPTH)	
1	5.5	5.5	5.0	5.0	5.0	-	5.0	-	5.0	(30 m)	-
1 rep	6.0	5.5	5.5	5.5	5.0	5.0	-	-	5.0	(27 m)	-
2	6.0	5.9	5.7	5.5	5.5	5.2	-	-	5.2	(25 m)	-
3	-	-	-	-	-	-	-	-	-	-	-
4	6.0	5.5	5.5	5.5	5.5	5.5	-	-	5.5	(25 m)	-
5	6.0	6.0	5.5	5.5	5.2	5.2	5.0	-	5.0	(30 m)	-
6	6.0	6.0	5.8	5.8	5.5	5.2	5.2	5.2	5.0	(42 m)	-
7	6.0	6.0	5.8	5.6	5.6	5.5	5.5	-	5.0	(50 m)	-
8	6.0	6.0	6.0	5.8	5.5	5.2	5.1	-	5.0	(48 m)	-
9	6.1	6.0	6.0	5.9	5.8	5.5	5.5	-	5.0	(45 m)	9
10	6.0	6.0	6.0	5.5	5.5	5.1	5.0	5.0	5.0	(35 m)	7
11	6.5	6.0	6.0	5.5	5.5	5.2	5.1	5.1	5.0	(40 m)	7
12	7.0	6.0	6.0	5.8	5.5	5.4	5.4	5.4	5.4	(40 m)	7
13	7.2	7.1	6.0	5.6	5.5	5.2	5.0	5.0	5.0	(50 m)	6
14	7.0	6.8	6.0	6.0	5.8	-	-	-	5.8	(15 m)	7
15	6.0	6.0	5.9	5.8	5.8	5.7	5.5	5.2	5.0	(50 m)	7
16	7.0	7.0	6.0	5.8	5.5	5.5	5.4	5.2	5.2	(35 m)	7
17	6.2	6.0	5.8	5.5	5.5	5.2	5.2	4.9*	4.9	(60 m)	8
18	6.0	6.0	5.9	5.9	5.5	5.4	5.2	-	5.0	(50 m)	10
19	6.0	5.9	5.8	5.5	5.2	5.0	5.0	-	5.0	(36 m)	-

---

* This measurement at 50 meters.

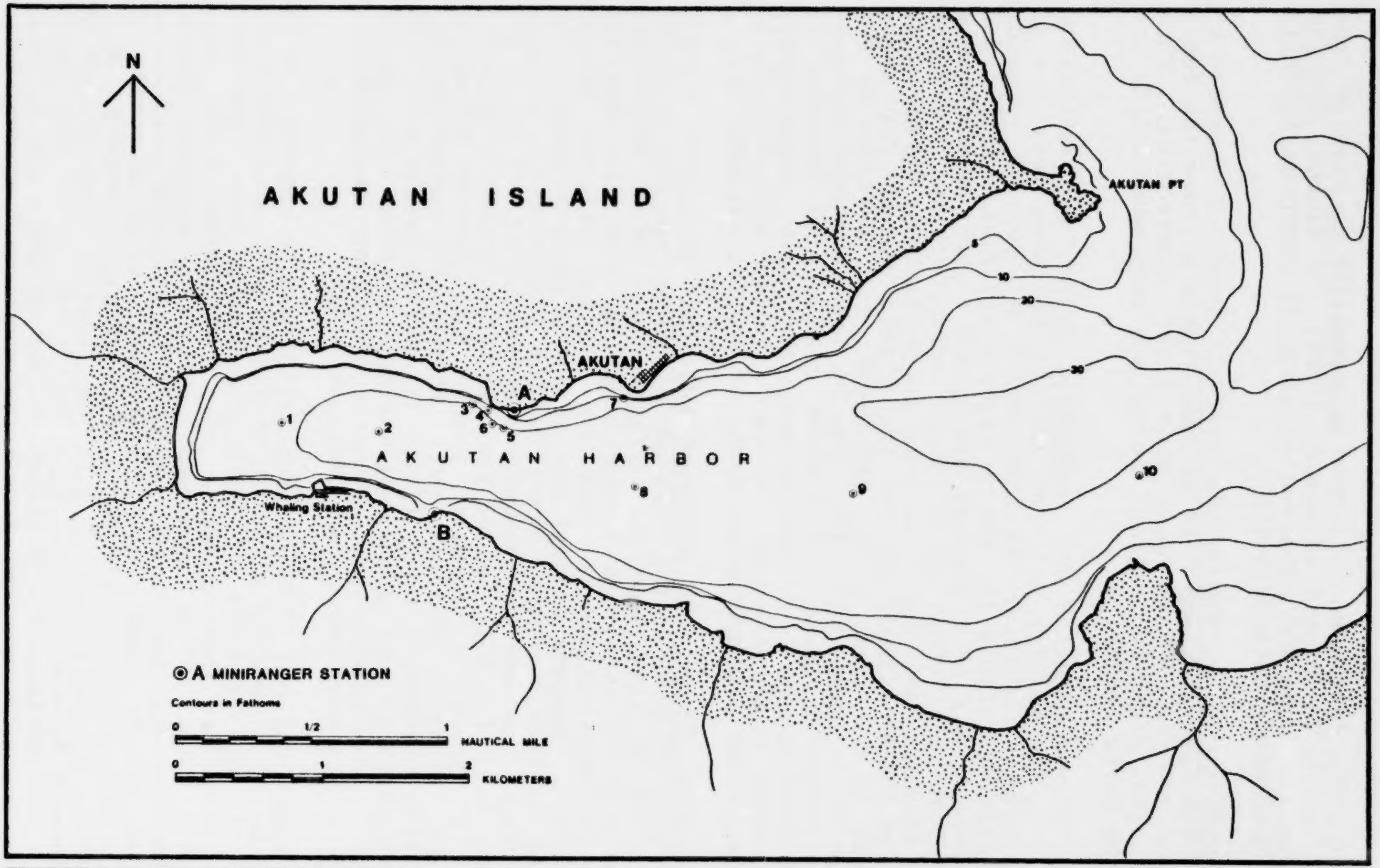
ADEC 1982). The data were collected sequentially by station from mid morning (0930) to mid afternoon (1500). A diurnal warming of the surface layer was observed at stations occupied later in the day (Sediment Stations 8-19).

Turbidity, Color, Settleable Solids. Secchi disk measurements at Sediment Stations 9-18 in June (Table 2) show the outer harbor to be clear, with very good light penetration. This indicates that dissolved organic matter and suspended solids are low in the outer harbor.

The values obtained for turbidity, color, and settleable solids at water quality stations (Figure 13) were very low in June. Measured turbidity was less than 1 NTU for all 10 water quality stations (Table 3), and no significant trends with depth were observed ($-.8<r<.8$ for all stations). Color measurements were discontinued after zero values were obtained at Water Quality Stations 1-3 and 5 in the inner harbor, where water clarity was most likely to be low. Zero values for these parameters in the inner harbor and Secchi disk readings in the outer harbor indicate that water clarity was very good throughout the harbor in June. Settleable solids were measured at Water Quality Station 4 on the Trident waste pile, where values were expected to be highest. However, values were <0.1 ml/l; measurements for this parameter were, therefore, discontinued.

Dissolved Oxygen and Hydrogen Sulfide. Dissolved oxygen was measured in June in the near bottom water samples at eight of 10 water quality stations (Figure 13). This monitoring included most of the inner harbor stations, stations near the Trident Seafoods discharge, and one station off the Akutan Village dock. Temperature was not measured simultaneously with dissolved oxygen; however, based on the previous day's water temperatures, an assumed bottom temperature of 5°C (mean and std. dev: 5.0° ± 0.1°), 19,000 ppm chloride concentration, and 760 mm Hg barometric pressure yields a saturated dissolved oxygen concentration of 10.14 mg/l. No measured concentrations reached this saturation level (Table 4), but no levels were less than 90 percent of the calculated saturation value. The bottom waters of Akutan Harbor were, therefore, well oxygenated during June 1983, even near known seafood waste piles.

Hydrogen sulfide (H_2S) concentrations can be expected to be highest in the immediate vicinity of discharge plumes and waste piles. All measurements of hydrogen sulfide were less than 2 ug/l, including bottom water on the Trident waste pile (Table 5). This is in agreement with the observed oxygen concentrations and the rapid oxidation of hydrogen sulfide in oxygenated waters. EPA (1976) has established a criterion of 2 mg/l of undissociated hydrogen sulfide in marine waters. With measurements of less than 2 ug/l and average oceanic pH of approximately 8, the undissociated concentration is well below 2 mg/l. The surface and midwater column measurement of this parameter was discontinued for Water Quality Stations 7-10,


N
AKUTAN ISLAND
AKUTAN PT
AKUTAN
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B
AKUTAN HARBOR
Whaling Station
1
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7
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9
10
5
10
20
30
⦿ A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 13. Location of Water Quality Stations. June 1983.

Table 3. Turbidity Measurements at Depth in June

WATER QUALITY STATION	TURBIDTY (NTU) SURFACE	50 ft*	70 ft*	BOTTOM	BOTTOM DEPTH (feet)	(meters)
1	0.41	0.39	0.35	0.50	111	33.8
2	0.40	0.35	0.33	0.85	140	42.7
3	0.42	0.31	0.40	0.87	120	36.6
4	0.44	0.54	0.38	0.34	95	29.0
5	0.42	0.30	0.42	0.50	125	38.1
6	0.55	0.39	0.34	0.62	130	39.6
7	0.44	0.39	-	-	-	-
8	0.44	0.35	0.35	0.94	155	47.2
9	0.74	0.65	0.36	0.42	160	48.8
10	0.59	0.40	0.31	0.65	180	54.9

---

* 50 ft = 15.2 m; 70 ft = 21.3 m.

Table 4. Dissolved Oxygen Near Bottom In June

WATER QUALITY STATION	D.O. (mg/l)	DEPTH feet	DEPTH meters	% SAT. AT 5°C
1	9.17	111	33.8	90.4
2	-	-		-
3	9.43	120	36.6	93.0
4	9.72	95	29.0	95.6
5	9.60	125	38.1	94.7
6	9.51	130	39.6	93.8
7	10.00	50	15.2	98.6
8	9.58	155	47.2	94.5
9	10.00	160	48.8	98.6
10	-	-		-

Table 5. Hydrogen Sulfide vs Depth in June

WATER QUALITY STATION	H_2S (mg/l) AT DEPTH SURFACE	50 ft*	70 ft*	BOTTOM	BOTTOM DEPTH (feet)	BOTTOM DEPTH (meters)
1	<.002	<.002	<.002	<.002	111	38.8
2	<.002	<.002	<.002	<.002	130	39.6
3	<.002	<.002	<.002	<.002	120	36.6
4	<.002	<.002	<.002	<.002	95	29.0
5	<.002	<.002	<.002	<.002	125	38.1
6	<.002	<.002	<.002	<.002	130	39.6
7	<.002	-	-	<.002	60	18.3
8	-	-	-	<.002	160	48.8
9	-	-	-	<.002	165	50.3
10	-	-	-	<.002	180	54.9

---

* 50 ft = 15.2 m; 70 ft = 21.3 m.

because dissolved oxygen and hydrogen sulfide concentrations in bottom water over the Trident waste pile indicated that measurements of hydrogen sulfide at "background" stations were unnecessary.

Oil and Grease. Near bottom water samples near waste piles (Water Quality Stations 3-6) were analyzed in June for oil and grease. The maximum value was 0.06 mg/l (Table 6) for Station 4, one of three stations on the Trident Seafoods' waste pile (Figure 13). All other values were less, and two were below the detection limit of 0.01 mg/l. Oil and grease should not form a visible sheen at these concentrations. Some sediment samples did have a sheen and may indicate oil and grease buildup in the sediments that was not detected in the overlying water column.

Nitrogen Ammonia (NH_3) was measured at all June water quality stations (Figure 13) and at all depths. The values ranged from <0.05 to 0.20 mg/l as nitrogen (Table 7), with Stations 1-6 having significantly higher values than Stations 7-10. No correlation between depth and concentration was observed. Assuming a pH of 8.3, approximately 3 percent of ammonia will be in the more toxic un-ionized form (Willingham 1976). This would convert the maximum value of 0.2 mg/l ammonia nitrogen to 0.006 mg/l of un-ionized ammonia nitrogen. While no EPA water quality criterion has been established for sea water or marine life, the freshwater standard has been set at 0.02 mg/l, threefold higher than the calculated un-ionized ammonia concentration.

Total Kjeldahl nitrogen, nitrate, and nitrite nitrogen were measured in June in the near bottom samples of the water quality stations near waste piles (Stations 3-6). High DO levels in water over the waste piles, even at near bottom depths, indicate little dissolved H_2S would be found. It was decided that further H_2S sampling would be unnecessary, and would be replaced by additional nitrogen sampling at the remaining stations. Therefore, these parameters were also measured at the surface and intermediate depths for Water Quality Stations 8-10 (Table 7). Nitrate levels increased with depth and were slightly higher for the near-bottom samples over the Trident Seafood waste piles. Station 7, near the Akutan Village dock, was below the detection limit for nitrate. Nitrite levels were below detection above the waste piles and were just over that limit for Stations 8-10. Higher nitrite values in the outer harbor water column may be associated in some manner with the observed higher ammonia concentrations in the sediments, relative to the inner harbor sediments. No correlation between NO_2 and depth was found. Nitrite is easily oxidized to nitrate and low values can be expected with oxygenated waters.

Kjeldahl nitrogen measurements allow for computation of organic nitrogen (e.g. proteins) after subtraction of the measured ammonia concentration. The data on Kjeldahl nitrogen and ammonia concentration (Table 7) show that organic nitrogen

Table 6. Oil and Grease vs Depth in June

WATER QUALITY STATION	OIL AND GREASE (mg/l) AT DEPTH			
			BOTTOM DEPTH	
	50 ft*	BOTTOM	(feet)	(meters)
1	-	-	-	
2	-	-	-	
3	-	0.01	120	36.6
4	-	0.06	95	29.0
5	-	0.02	125	38.1
6	-	<0.01	130	39.6
7	<0.01	-	-	
8-10	-	-	-	-

---

* 50 ft = 15.2 m

Table 7. Nitrogen (Ammonia, Kjeldahl, Nitrate, Nitrite) vs Depth in June

WATER QUALITY STATION	SURFACE				50 ft*				70 ft*				BOTTOM				DEPTH	
	NH_3	TKN	NO_3	NO_2	NH_3	TKN	NO_3	NO_2	NH_3	TKN	NO_3	NO_2	NH_3	TKN	NO_3	NO_2	feet	meters
1	0.11	-	-	-	0.12	-	-	-	0.12	-	-	-	0.10	-	-	-	111	33.8
2	0.08	-	-	-	0.10	-	-	-	0.19	-	-	-	0.09	-	-	-	130	39.6
3	0.07	-	-	-	0.05	-	-	-	0.07	0.11	0.19	<0.01	<0.05	0.05	0.40	<0.010	120	36.6
4	0.20	-	-	-	0.10	-	-	-	<0.05	-	-	-	0.06	0.15	0.58	<0.010	95	29.0
5	0.06	-	-	-	0.08	-	-	-	0.08	-	-	-	0.09	0.14	0.55	<0.010	125	38.1
6	0.05	-	-	-	<0.05	-	-	-	<0.05	-	-	-	0.19	0.23	0.26	<0.010	130	39.6
7	<0.05	-	-	-	-	-	-	-	-	-	-	-	<0.05	0.11	<0.10	<0.010	60	18.3
8	<0.05	<0.05	<0.10	0.014	<0.05	<0.05	<0.10	0.012	<0.05	< .05	0.11	0.015	0.06	0.06	0.34	0.013	160	48.8
9	0.05	0.05	<0.10	0.015	0.12	0.12	0.11	0.012	<0.05	< .05	0.12	0.012	<0.05	-	-	-	165	50.3
10	<0.05	<0.05	0.17	0.012	<0.05	<0.05	<0.10	0.012	<0.05	0.08	0.13	0.012	<0.05	-	-	-	180	54.9

* 50 ft = 15.2 m; 70 ft = 21.3 m.

NH_3 = Ammonia-Nitrogen mg/l

TKN = Total Kjeldahl Nitrogen mg/l

NO_3 = Nitrate-Nitrogen mg/l

NO_2 = Nitrite-Nitrogen mg/l

occurs in the near-bottom water around waste piles (range 0.04 - 0.09 mg/l), but is not present in the water column in the outer harbor.

Salinity. Salinity measurements were performed in the laboratory on the near-bottom samples from Water Quality Stations 3-7 during the June survey. The average of these five measurements is 28.7 parts per thousand (ppt). The Bering Sea has a salinity ranging from 32.6-33.2 ppt (Jones & Stokes Associates 1983), significantly higher than those observed in Akutan Harbor. The data collected by ADEC (1982) ranged from 22-28 ppt, which is in agreement with observed values during June.

September Data

Unlike June water quality data, all water quality data collected in September were taken at 20 water quality stations (Figure 14), i.e., no water quality data were collected at September sediment stations. Water Quality Station 19 in September was located at the north end of Akun Strait, a few hundred meters west of the June Sediment Station 19 (Figure 12).

Temperature and Salinity. Water temperatures in Akutan Harbor in September were nearly isothermal both vertically and horizontally, ranging from 7.7 to 8.3°C. Salinity within the harbor ranged from about 28.9 to 31.3 parts per thousand (ppt). Vertically, the water column was well mixed. The water column was stable with a small increase in density with depth. The magnitude of the density increase varied considerably between stations. The salinity temperature, density, and pH values observed at each station are shown in Appendix D.

Figure 15 displays vertical profiles of salinity, temperature, and density [sigma tau (   )] at September Water Quality Stations 2, 4, 7, 13, 16, and 18. These stations represent a transect from the head of the harbor to Akun Bay. The density profiles within the harbor exhibit more vertical variation than the station in Akutan Bay. This is probably because of the greater interaction of the flow with the boundary within Akutan Harbor. The highest rate of change in salinity and density occurs in an upper layer that varies from 5 to 20 m deep.

The horizontal salinity distribution is quite variable. The depth-averaged salinity for each water quality station is shown in Figure 11. The average salinity in Akutan Bay (Stations 18, 19 and 20) is 31.61 ppt. Salinities within Akutan Harbor are lower, reflecting the input of freshwater. The lack of clear horizontal salinity gradients is probably due to unsteady circulation patterns.

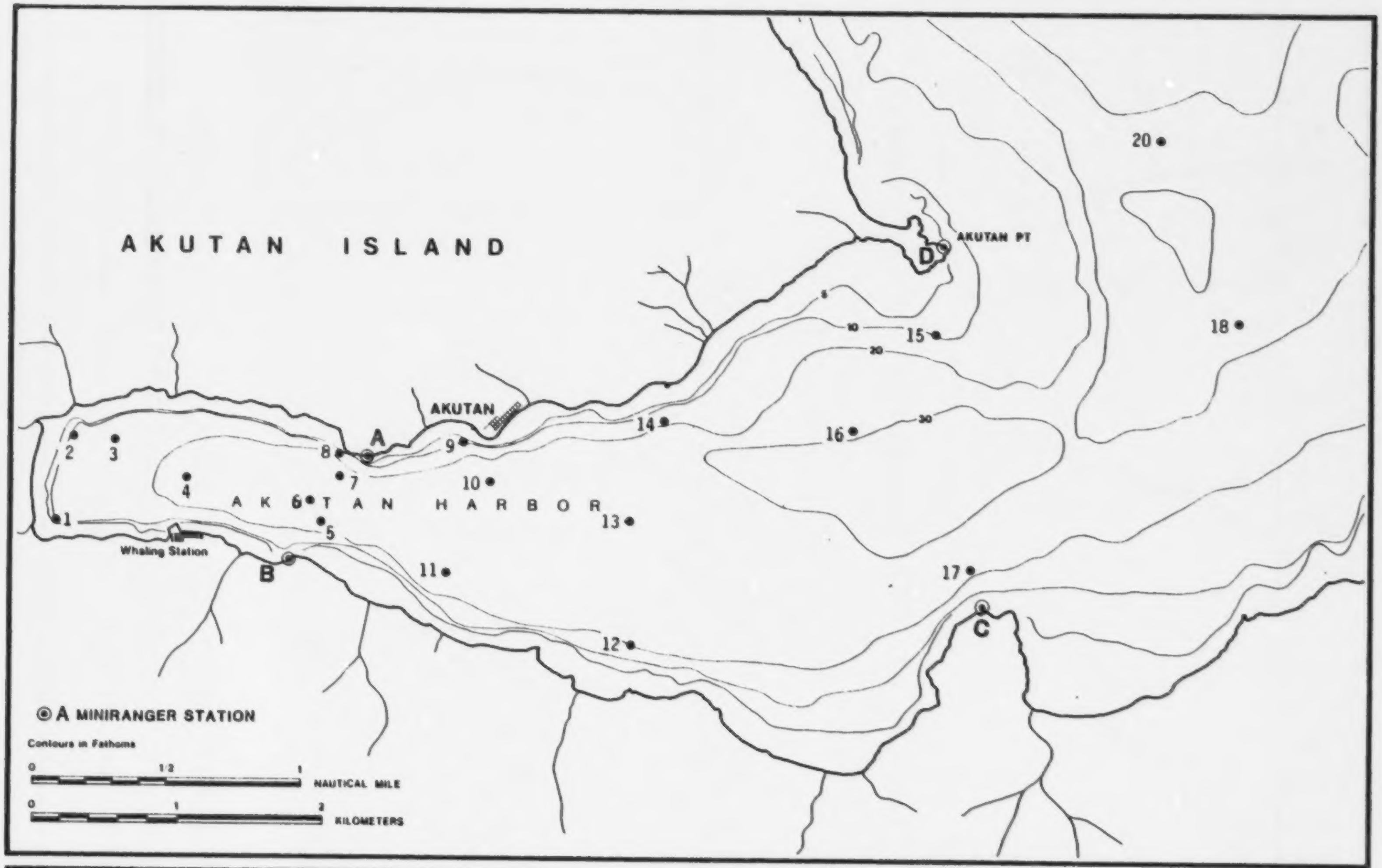

AKUTAN ISLAND
AKUTAN PT
D
AKUTAN
A
B
C
AKUTAN HARBOR
Whaling Station
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
8
10
20
30
⊙ A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 14. Location of Water Quality Stations. September 1983.

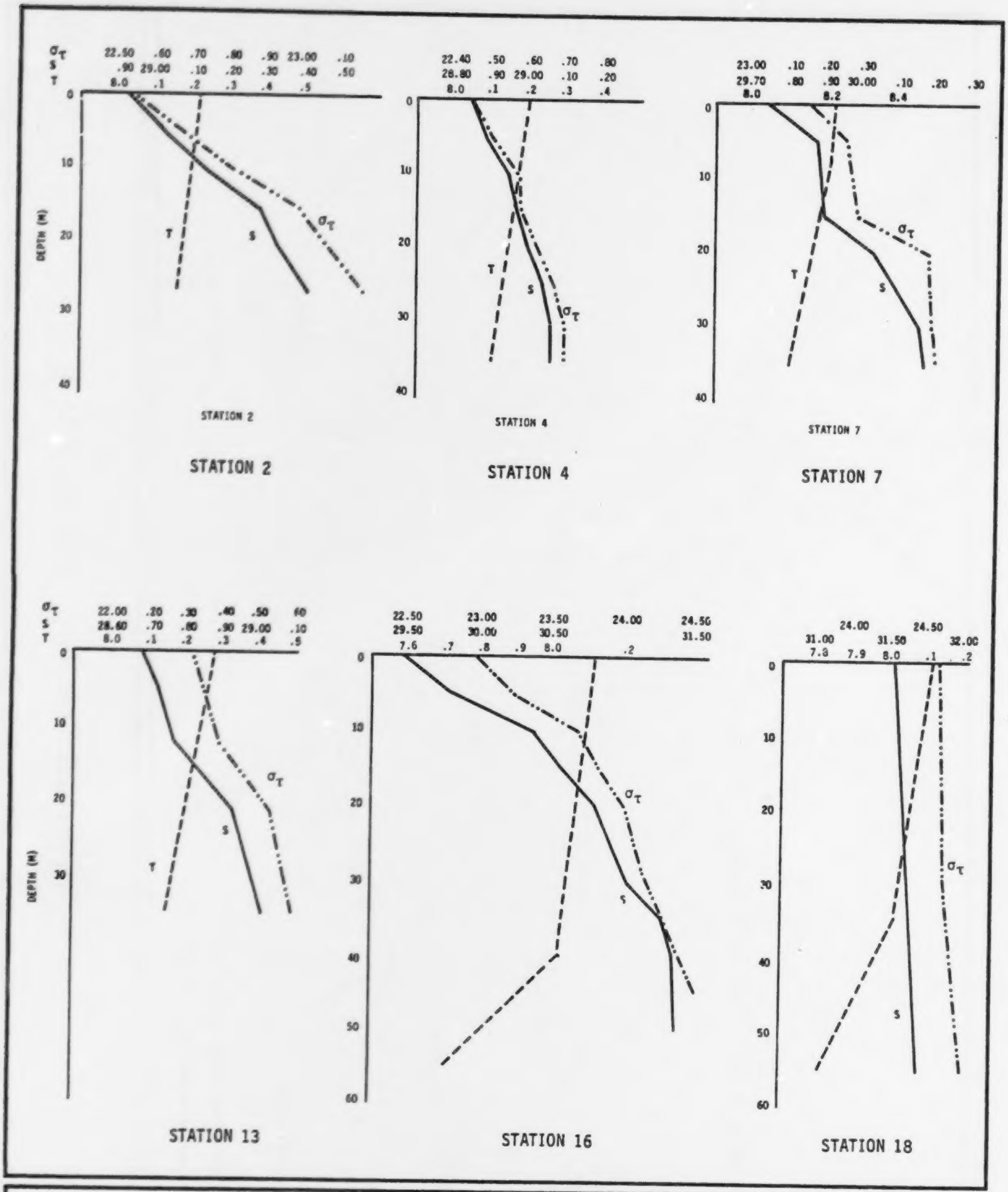


Figure 15. Density (σ_T), Salinity (s), and Temperature (T) Profiles. September 1983.

Turbidity. Measurement of turbidity in September showed slightly higher values (Table 8) than in June (Table 3). A one-way ANOVA test of mean surface turbidity for June and September showed a significant difference at a 95 percent confidence level. Higher turbidity in September may be a product of the summer phytoplankton bloom.

Secchi disc readings in September (Water Quality Stations 9-19) were taken in overcast weather between 1400 and 1800 hours on 16 September. Water Quality Stations 1-8 in September were occupied after 1800 hours, when light conditions prevented use of the Secchi disc. Station 20 was occupied during fog at 1500 hours on 18 September. The data ranged from 6.5-10 m, with a mean value of 8 m. With the exception of Station 17, values decreased toward the inner harbor (Table 8). These data could be affected by decreasing light over the course of the afternoon. In general, Secchi disc readings and turbidity measurements indicate generally clear water in Akutan Bay and Akutan Harbor in September.

Dissolved Oxygen. The September surface dissolved oxygen concentrations determined by titration are shown in Table 9 along with the dissolved oxygen saturation concentration computed from the observed temperature and salinity. All values are within 95 percent of saturation.

Although the Martek water quality data logger was calibrated in air by Martek prior to the survey and again calibrated in the field prior to deployment, dissolved oxygen concentrations measured with the probe were consistently about 20 percent higher than the values measured by titration. The probe appeared to otherwise be responding properly. None of the probe values, measured continuously from the bottom to the surface at each station, indicated any significant depression of dissolved oxygen concentrations below saturation anywhere within Akutan Harbor. The probe and titrating equipment were tested and calibrated following field work, and no mechanical problems were found. It is possible that the difference in values is a product of consistent procedural bias during the Winkler titration.

Sediment Studies

The data gathered for sediment analysis consisted of side-scan sonar surveys and benthic grab samples.

Side-Scan Sonar Surveys (June)

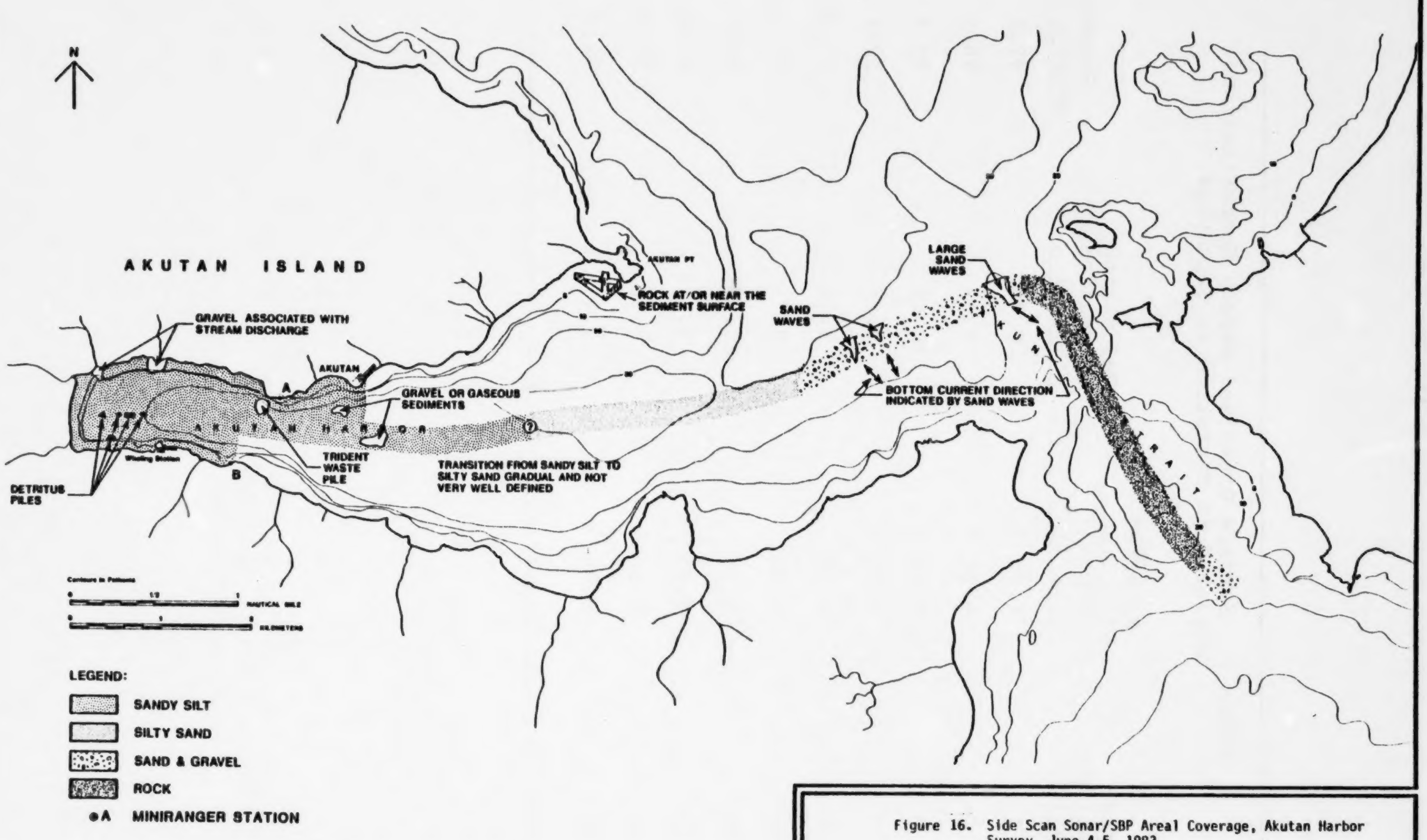
On June 4, a 100 kHz side-scan sonar track was run from the southern entrance of Akun Strait northward through the strait and westward to the head of Akutan Harbor (Figure 16). Additional tracks were run with the 500 kHz system, which

Table 8. Turbidity Measurements Taken in September

Water Quality Station	Depth (m)	Turbidity (NTU)	Secchi Disc m	Water Quality Station	Depth (m)	Turbidity (NTU	Secchi Disc (m)
1	Surface	0.60	-	11	Surface	0.82	7
1	20	0.78		11	45	0.55	
2	Surface	0.66	-	12	Surface	0.56	10
2	25	0.69		12	40	0.55	
3	Surface	0.63	-	13	Surface	0.87	8.5
3	30	0.47		13	50	0.64	
4	Surface	0.55	-	14	Surface	1.30	7.0
4	35	0.62		14	30	0.76	
5	Surface	0.60	-	15	Surface	0.37	8.5
5	40	0.70		15	18	0.55	
6	Surface	0.53	-	16	Surface	0.35	8.0
6	45	0.55		16	60	1.10	
7	Surface	1.50	-	17	Surface	1.30	6.5
7	40	1.00		17	35	1.70	
8	Surface	0.62	-	18	Surface	2.30	8.0
8	30	0.42		18	50	1.60	
9	Surface	0.96	7	19	Surface	1.20	9.5
9	9	1.20		19	30	1.70	
10	Surface	0.95	7	20	Surface	0.96	10
10	40	0.56		20	70	0.39	

Table 9. Surface Dissolved Oxygen Concentrations Measured in Titration in September

Water Quality Station	Measured Dissolved Oxygen (mg/l)	Calculated Saturation (mg/l)	Percent Saturation
1	9.54	9.78	97.5
2	9.53	9.83	96.9
6	9.63	10.15	94.9
7	9.69	9.78	99.1
8	9.53	9.73	97.9
15	9.42	9.74	97.7
16	9.50	10.02	94.8
18	9.50	9.71	97.8
19	9.50	9.72	97.7
20	9.36	9.71	96.4



N
AKUTAN ISLAND
AKUTAN PT
ROCK AT/OR NEAR THE SEDIMENT SURFACE
GRAVEL ASSOCIATED WITH STREAM DISCHARGE
AKUTAN
A
GRAVEL OR GASEOUS SEDIMENTS
AKUTAN HARBOR
TRIDENT WASTE PILE
B
DETRITUS PILES
TRANSITION FROM SANDY SILT TO SILTY SAND GRADUAL AND NOT VERY WELL DEFINED
SAND WAVES
LARGE SAND WAVES
BOTTOM CURRENT DIRECTION INDICATED BY SAND WAVES
AKUN STRAIT
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
LEGEND:
SANDY SILT
SILTY SAND
SAND & GRAVEL
ROCK
● A MINIRANGER STATION

Figure 16. Side Scan Sonar/SBP Areal Coverage, Akutan Harbor Survey, June 4-5, 1983.

essentially covered the entire inner harbor west of Akutan Village. On the following day, 3.5 kHz SBP tracklines were completed in the vicinity of Akutan Point (a proposed boat harbor site), across a waste pile near Akutan Village, across the Trident outfall and associated waste pile, and across several waste piles in the inner harbor, which had previously been identified by side-scan sonar.

The 100 kHz side-scan sonar transect from Akun Strait to the head of Akutan Harbor revealed a progression in bottom types, from exposed rock swept clean of any sediment cover through the Strait, to sandy silt from Akutan Village to the head of the harbor. Sand waves were found in three areas near the mouth of the harbor. The sand waves occurring nearest the strait were large, exhibiting wave lengths of 5 m and heights of more than 0.5 m. As one might expect, orientation of these large sand waves indicated water motion parallel to Akun Strait (NW-SE). In the other two areas, the sand waves were smaller in size (wave lengths of less than 2 m), and exhibited orientation suggesting bottom water motion parallel to a NNW-SSE line.

Several waste piles were located in addition to the processing waste associated with the Trident Seafoods outfall (Figure 16). A low relief feature characterized by high acoustic reflectivity was found south of Akutan Village, and five well defined piles of material were located near the head of the harbor. The pile near the whaling station had approximate dimensions of 45 m by 50 m by 3 m high. From east to west, the approximate dimensions of the piles along the central axis of the inner harbor were as follows:

Length	Width	Height
35 m	30 m	0.6 m
95 m	75 m	3.5 m
16 m	22 m	2 m
8 m	8 m	1 m

Two areas of gravel, apparently from stream discharge, were also identified. Numerous drag marks were noted on the bottom of the inner portions of the harbor, indicating extensive use as an anchorage.

Several tracklines were run with the 500 kHz high resolution side-scan sonar to further define the waste pile around Trident Seafoods' discharge. With both 100 and 500 kHz units the waste pile exhibited high acoustic reflectivity, probably due to the presence of gas in the near surface material. From the side-scan sonographs, the Trident Seafoods waste pile appeared to be approximately 7 m high and 200 m in diameter. The sonograph indicated that the bulk of the deposited solids are located in a pile over the outfall. There was no evidence that the pile tailed off in a particular (downcurrent) direction.

On June 5, 3.5 kHz SBP records were obtained from the Trident Seafoods' waste pile, a pile near the Akutan Village dock, and several of the piles identified near the head of the harbor. The SBP cross section of the Trident outfall discharge site revealed a 5.8 m pile of material overlaying the natural bottom, somewhat less than the height indicated by side-scan sonar. Although height measurements by both methods were in close agreement, the greater value produced from the side-scan sonograph may indicate that the SBP profile did not cross the waste pile at its highest point. At the Akutan Village dock, a 2.3 m pile was located, and near the head of the harbor two of the piles previously found with side scan were profiled, the largest being 3.5 m in height.

June Sediment Data

Table 10 summarizes data from the June sediment sampling that was performed at 37 sediment stations (Figure 11). TOC results are expressed as percent dry weight. Sediment Station 31 was not analyzed for fines due to its high gravel and sand content. Sediment Station 19 in Akun Strait was found to have a rock bottom which could not be successfully sampled by the Van Veen grab. A fist-sized rock was retrieved and visually examined, but not retained for further analysis. Station 23 was located directly over the Trident Seafoods discharge and the grab contained pure seafood waste and thus was not subsampled. Station 25 was sampled for visual analysis only and was not subsampled. Stations 33-36 were located to sample an aged waste pile, and Station 36 was subsampled to be representative of the pile.

The data presented in Table 10 are presented graphically in Figures 17 through 19. From these figures a clear distinction can be made in June between the inner and outer harbors. The outer harbor has low TOC values (Figure 17), sand-dominated sediments (Figure 18), and higher ammonia-nitrogen concentrations (Figure 19). Sediment character near waste piles (Stations 2, 3, 19B-36) varies from the background inner harbor (Stations 1, 5-9, 11) for at least one of these parameters, perhaps as a result of processing activities.

September Sediment Data

In September, sediment chemistry data were collected at six stations (S1-S6, Figure 20) with 3 or 5 grab samples within the station area. Table 11 summarizes mean and standard deviation of September sediment parameters. Station S1 was located in an

Table 10. Sediment Sampling Performed at Sediment Stations in June

STATION	TOC (%)	GRAIN SIZE			AMMONIA (ppm)
		% SAND	% FINE	TYPE[1]	
1	0.34	60	40	N. Silty Sand	2.9
1 rep	0.22	1	99	N. Clayey Silt	3.2
2	0.13	20	20	N. Sandy Gravel	5.7
3	0.38	45	45	N. Silty Sand	6.8
4	0.25	50	50	N. Silty Sand	3.2
5	0.20	40	60	N. Sandy Silt	0.7
6	0.50	30	70	N. Clayey Silt	1.7
7	0.13	35	65	N. Sandy Silt	2.3
8	0.29	48	50	N. Silty Sand	1.1
9	0.26	30	68	N. Sandy Silt	4.4
10	<0.01	70	25	N. Silty Sand	84.0
11	0.21	35	65	N. Sandy Silt	1.3
12	0.09	60	40	N. Silty Sand	29.0
13	0.01	99	1	U. Medium Sand	15.0
14	<0.01	99	1	U. Fine Sand	30.0
15	0.08	50	50	N. Silty Sand	15.0
16	<0.01	70	30	N. Silty Sand	24.0
17	<0.01	60	40	N. Silty Sand	24.0
18	<0.01	75	25	N. Silty Sand	3.0
19*	-	-	-	-	-
19B	<0.01	90	3	U. Medium Sand	8.8
20**	0.04	60	40	N. Silty Sand	11.0
21	0.34	40	60	N. Sandy Silt	3.7
22**	0.71	65	35	N. Silty Sand	75.0
23**	-	-	-	-	-
24**	0.03	70	30	N. Silty Sand	26.0
25**	-	-	-	-	-
26	0.15	60	28	N. Silty Sand	8.2
27	0.23	65	20	N. Gravelly Sand	41.0
28	0.15	90	8	N. Fine Sand	2.5
29***	0.08	92	8	N. Fine Sand	10.0
30	0.06	68	32	N. Silty Sand	3.1
31***	0.32	27	-	N. Sandy Gravel	14.0
32***	0.06	88	12	N. Fine Sand	6.1
33	-	-	-	-	-
34	-	-	-	-	-
35	-	-	-	-	-
36	0.03	77	8	N. Gravelly Sand	3.7

---

[1] N = Nonuniform, U = Uniform.
* Rocky bottom in Akun Strait.
** Trident waste pile.
*** Akutan Village waste pile.

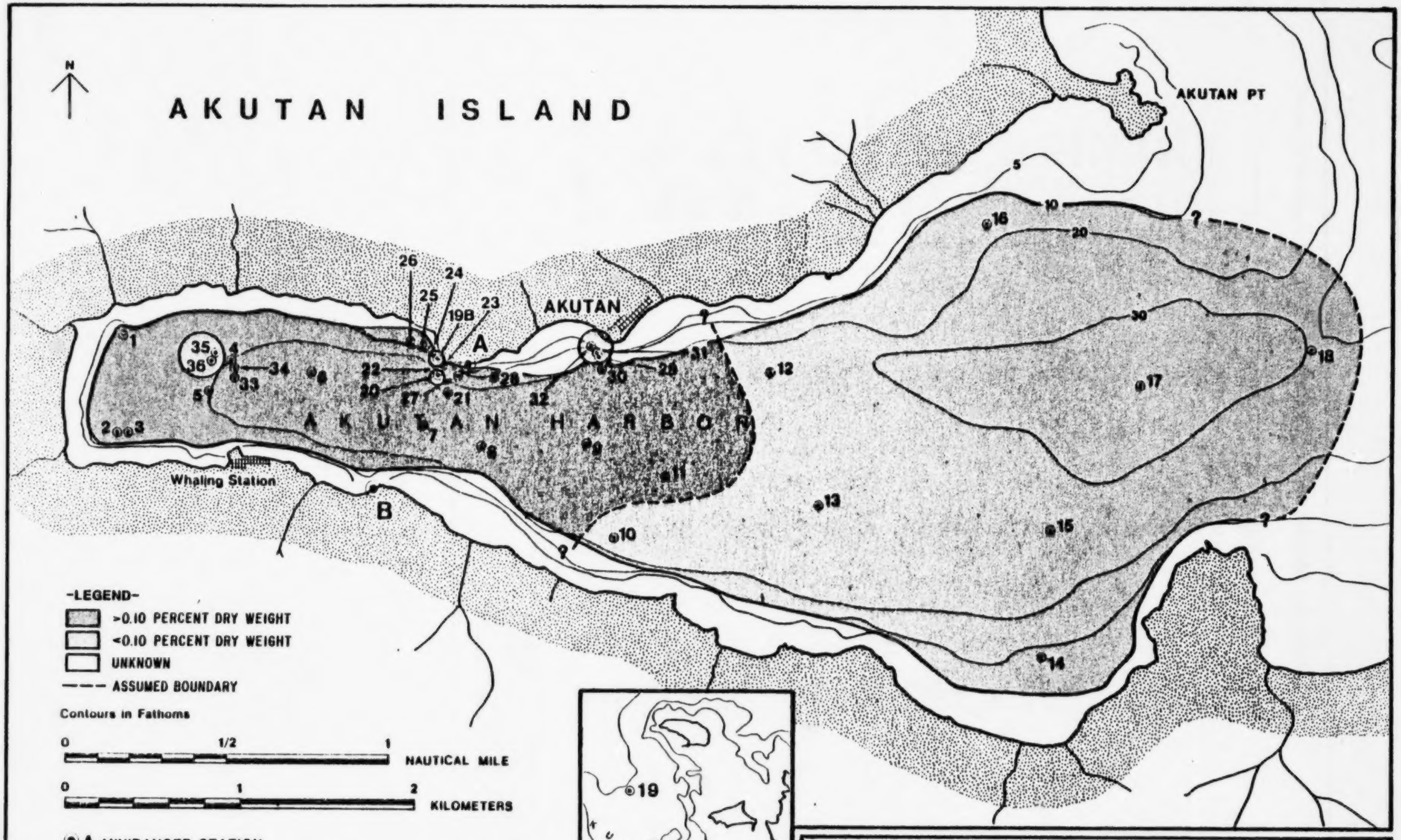
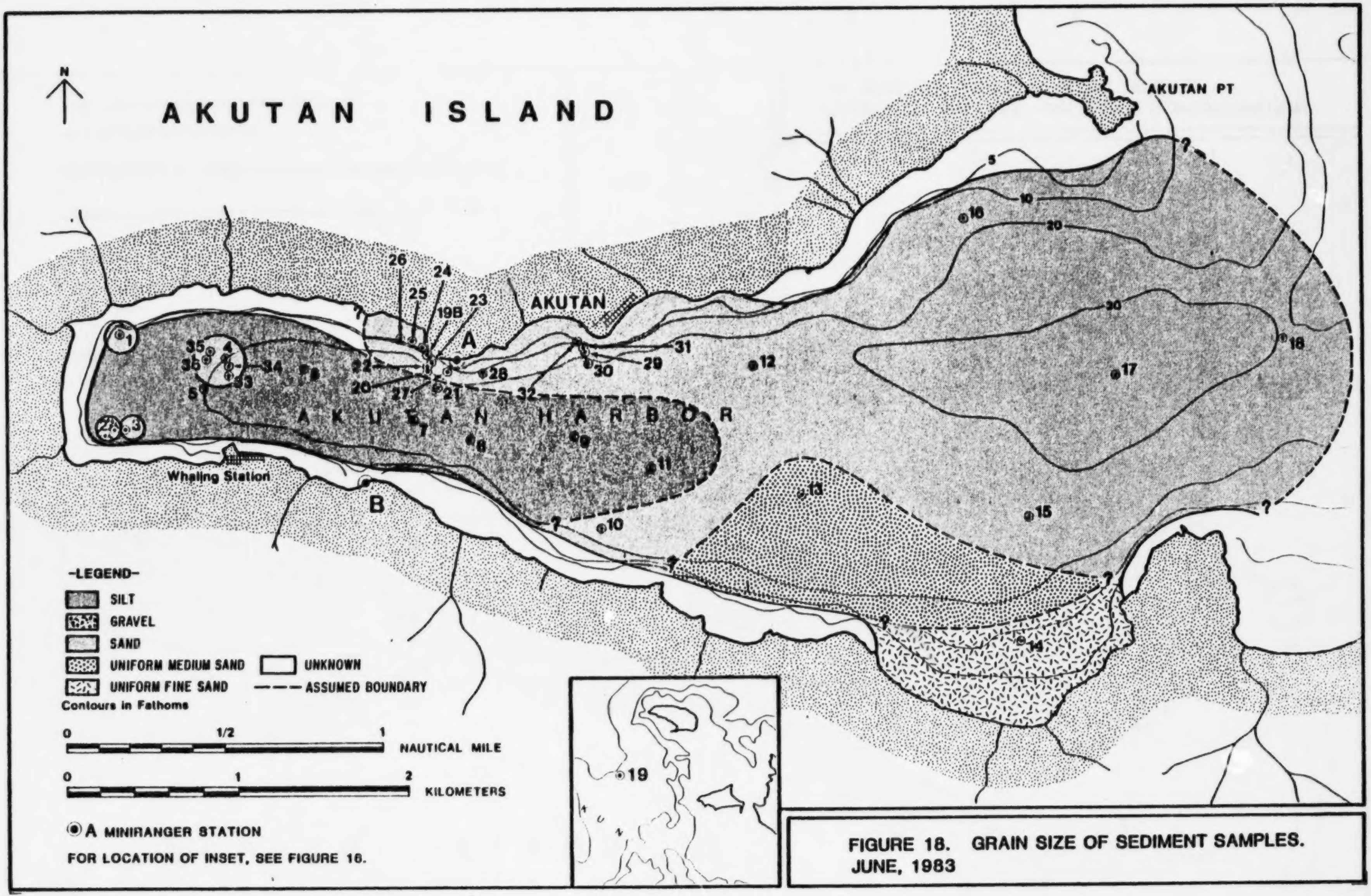

N
AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
A
B
5
10
20
30
?
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
19B
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
-LEGEND-
▨ >0.10 PERCENT DRY WEIGHT
☐ <0.10 PERCENT DRY WEIGHT
☐ UNKNOWN
--- ASSUMED BOUNDARY
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
◉ A MINIRANGER STATION
FOR LOCATION OF INSET, SEE FIGURE 16.

FIGURE 17. TOTAL ORGANIC CARBON IN SEDIMENT SAMPLES. JUNE, 1983


N
AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
A
B
1
2B
3
4
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6
8
9
10
11
12
13
14
15
16
17
18
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19B
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26
27
28
29
30
31
32
33
34
35
36
5
10
20
30
?
-LEGEND-
SILT
GRAVEL
SAND
UNIFORM MEDIUM SAND
UNIFORM FINE SAND
UNKNOWN
ASSUMED BOUNDARY
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
A MINIRANGER STATION
FOR LOCATION OF INSET, SEE FIGURE 16.

FIGURE 18. GRAIN SIZE OF SEDIMENT SAMPLES.
JUNE, 1983

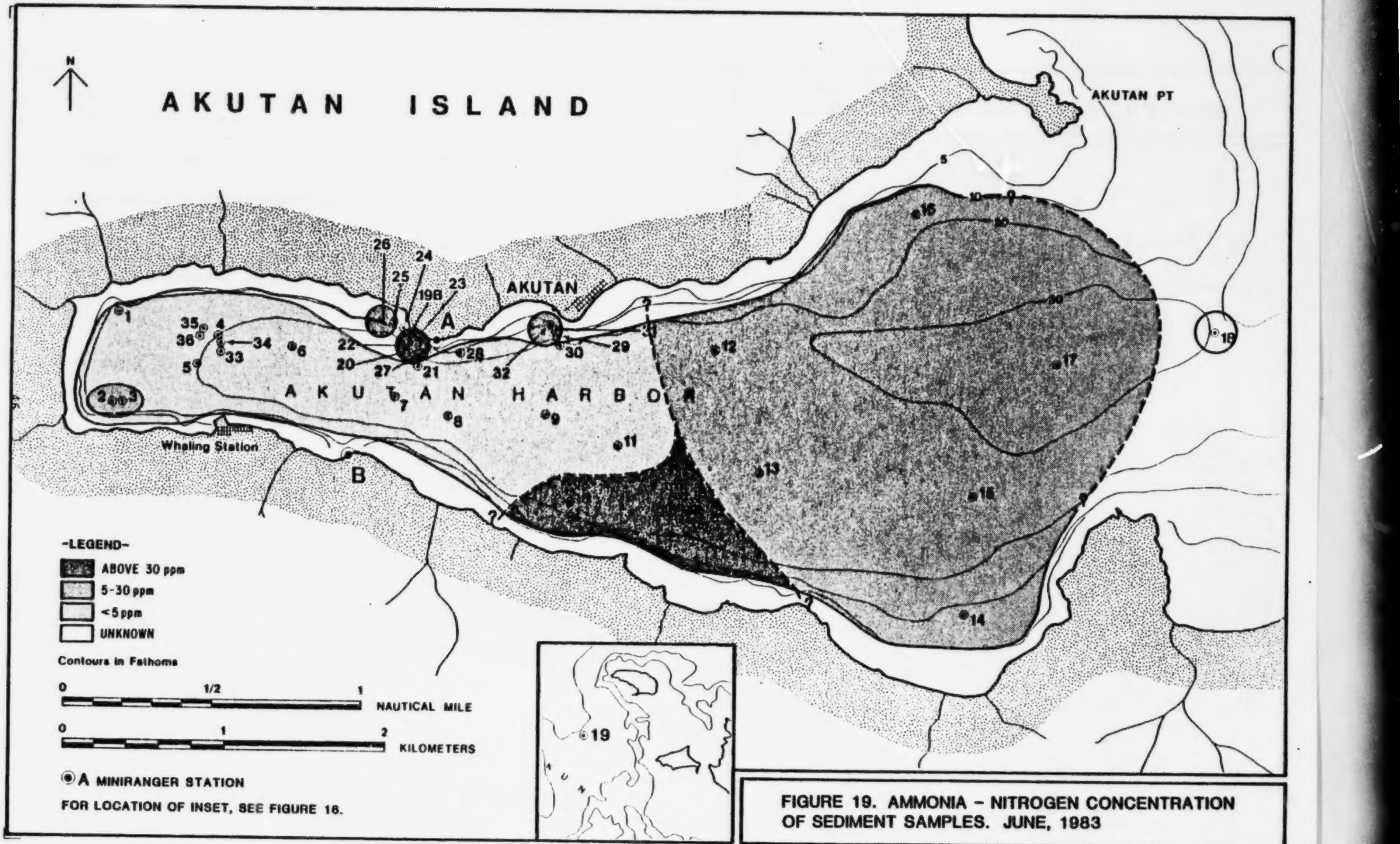
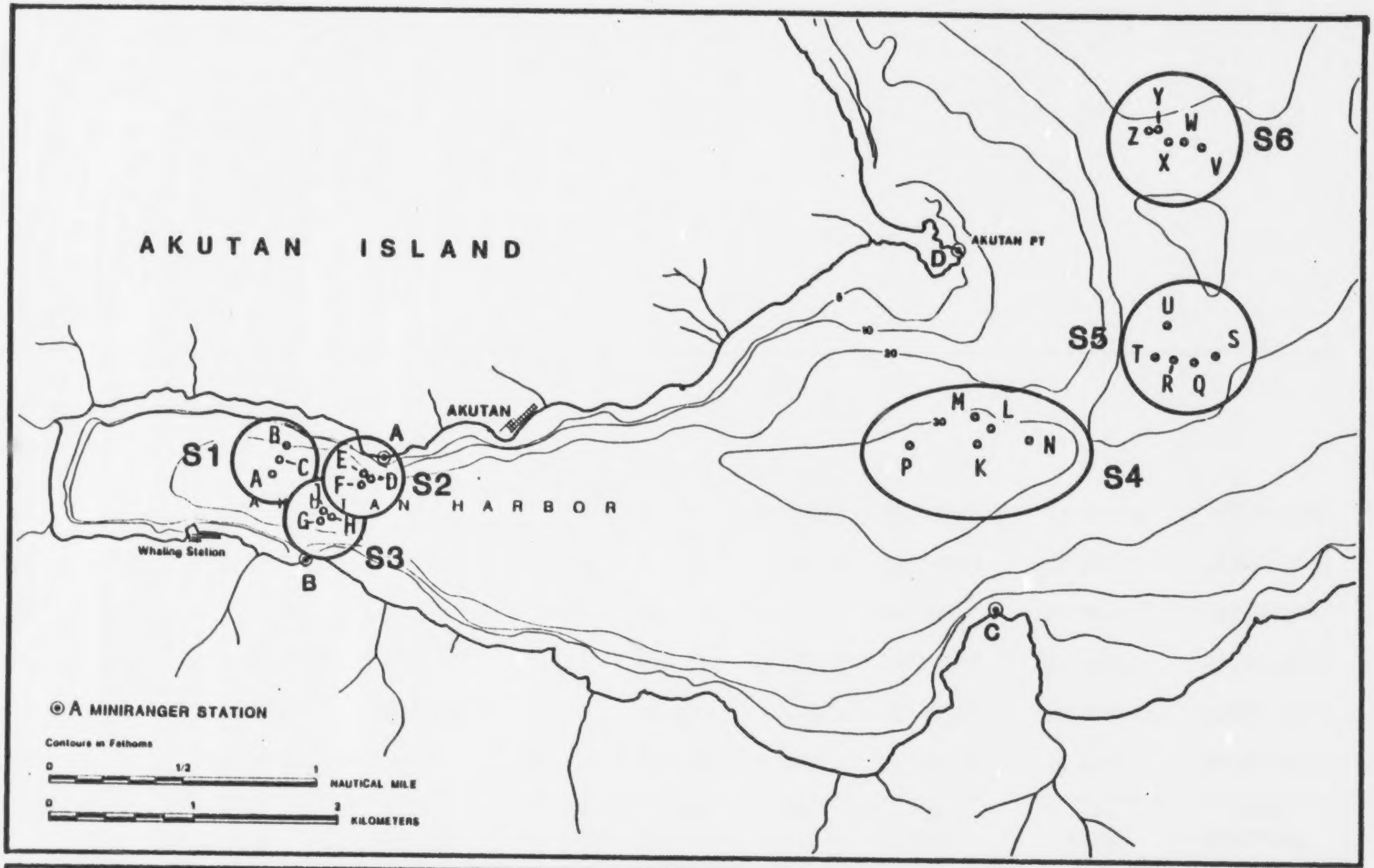

N
AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
A
B
1
2
3
4
5
6
7
8
9
11
12
13
14
15
16
17
18
19
19B
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
5
10
20
30
-LEGEND-
ABOVE 30 ppm
5-30 ppm
<5 ppm
UNKNOWN
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
A MINIRANGER STATION
FOR LOCATION OF INSET, SEE FIGURE 16.

FIGURE 19. AMMONIA - NITROGEN CONCENTRATION OF SEDIMENT SAMPLES. JUNE, 1983


AKUTAN ISLAND
AKUTAN HARBOR
AKUTAN
AKUTAN PT
Whaling Station
S1
S2
S3
S4
S5
S6
A
B
C
D
E
F
G
H
I
J
K
L
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P
Q
R
S
T
U
V
W
X
Y
Z
8
10
20
30
⊙ A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 20. Sediment Sampling Stations. September 1983.

Table 11. Mean ± Standard Deviation Values for Sediment Parameters in September

STATION	N	TOC[1] %	SULFIDE ppm	AMMONIA ppm	ORGANIC NITROGEN ppm	pH	SAND %	FINES %	SEDIMENT TYPE
S1	3	1.47±0.25	20±10	15±4	639±168	7.4±0.1	21.1±6.0	78.8±6.0	Sandy Silt
S2	3	1.03±0.40	1075±1025	27±23	947±306	7.4±0.2	43.8±10.0	56.3±10.5	Sandy Silt
S3	3	0.84±0.09	30±10	16±9	410±125	7.4±0.1	62.5±3.3	37.4±3.6	Silty Sand
S4	5	1.03±0.32	36±37	17±8	501±331	7.4±0.1	58.5±14.5	41.4±14.5	Silty Sand
S5	5	0.59±0.14	- -	- -	- -	7.4±0.1	79.5±3.2	20.5±3.3	Silty Sand
S6	5	0.81±0.20	- -	- -	- -	7.6±0.1	82.4±4.5	17.7±4.6	Silty Sand

---

[1] Percent dry weight

area that showed a possibly impacted benthic community in June. Station S2 was located near the perimeter of the Trident waste pile. Stations S3 and S4 were located in presumed background areas in the inner and outer harbor, respectively. Stations S5 and S6 were located in Akutan Bay, and are being considered as solid waste dump sites for the City of Akutan. Sediments at these latter two stations were not analyzed for sulfide, ammonia, and organic nitrogen. Appendix F is a complete listing of sediment data gathered at each station. The data presented in Table 11 are presented graphically in Figures 21 through 25.

Sediment of Station S2, near the Trident waste pile, has higher values for sulfide, ammonia, and organic nitrogen than other September stations. These elevated levels probably result from the wastes.

Average TOC levels (Table 11, Figure 22) were greater than 1 percent for Stations S1, S2, and S4; mean values of each of these three stations were within the standard deviation of the other two. TOC was significantly higher at Station S1 relative to Stations S3, S5, and S6. Ammonia levels (Table 11, Figure 23) do not vary significantly between stations, although Station S2, near the Trident waste pile, has the highest average concentration. Organic nitrogen at Station S2 is the highest observed and is significantly greater than Station S3 (Table 11, Figure 24). Station S1 is also noticeably higher in organic nitrogen than Stations S3 and S4, but the difference is not significant. Sulfide concentrations at S2 were significantly greater than at S1, S3, and S4 (Table 11, Figure 25).

With the exception of grain size (Figure 21), the distinction between inner and outer harbor sediment chemistry that was visible in June had vanished in September. Ammonia levels (Figure 20) generally increased in the inner harbor; two stations (S1, S3) showed significant increases between June and September. The outer harbor station (S4) showed a decrease in ammonia levels, but the June value is within the standard deviation of the September data. TOC values (Figure 21) significantly increased from June to September.

Biological Community - June 1983

The locations of benthic community sampling stations in June are shown in Figure 26. These correspond to June sediment sampling stations (Figure 12). Sediment Stations 1-19 were initially selected to characterize the harbor bottom community away from waste piles ("background stations"). Because of field scheduling constraints, selection of background stations was made prior to determining location of waste piles with side-scan sonar equipment. Sediment Stations 1-3 and 5-18 are presumed to be characteristic of the harbor bottom. It was discovered later

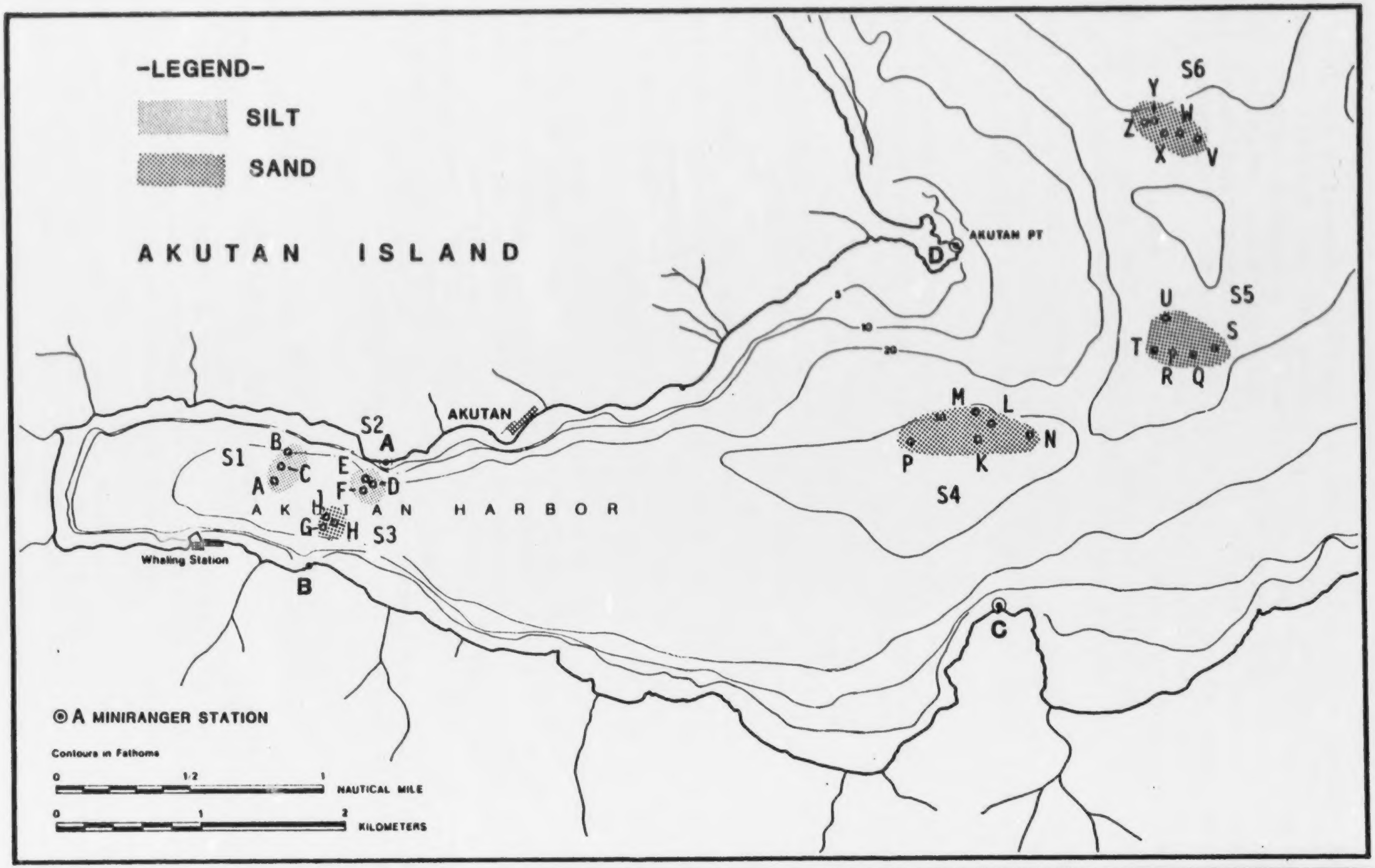

-LEGEND-
▨ SILT
▨ SAND
AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
S1
S2
S3
S4
S5
S6
A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
Q
R
S
T
U
V
W
X
Y
Z
5
10
20
◉ A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 21 . Grain Size in September 1983

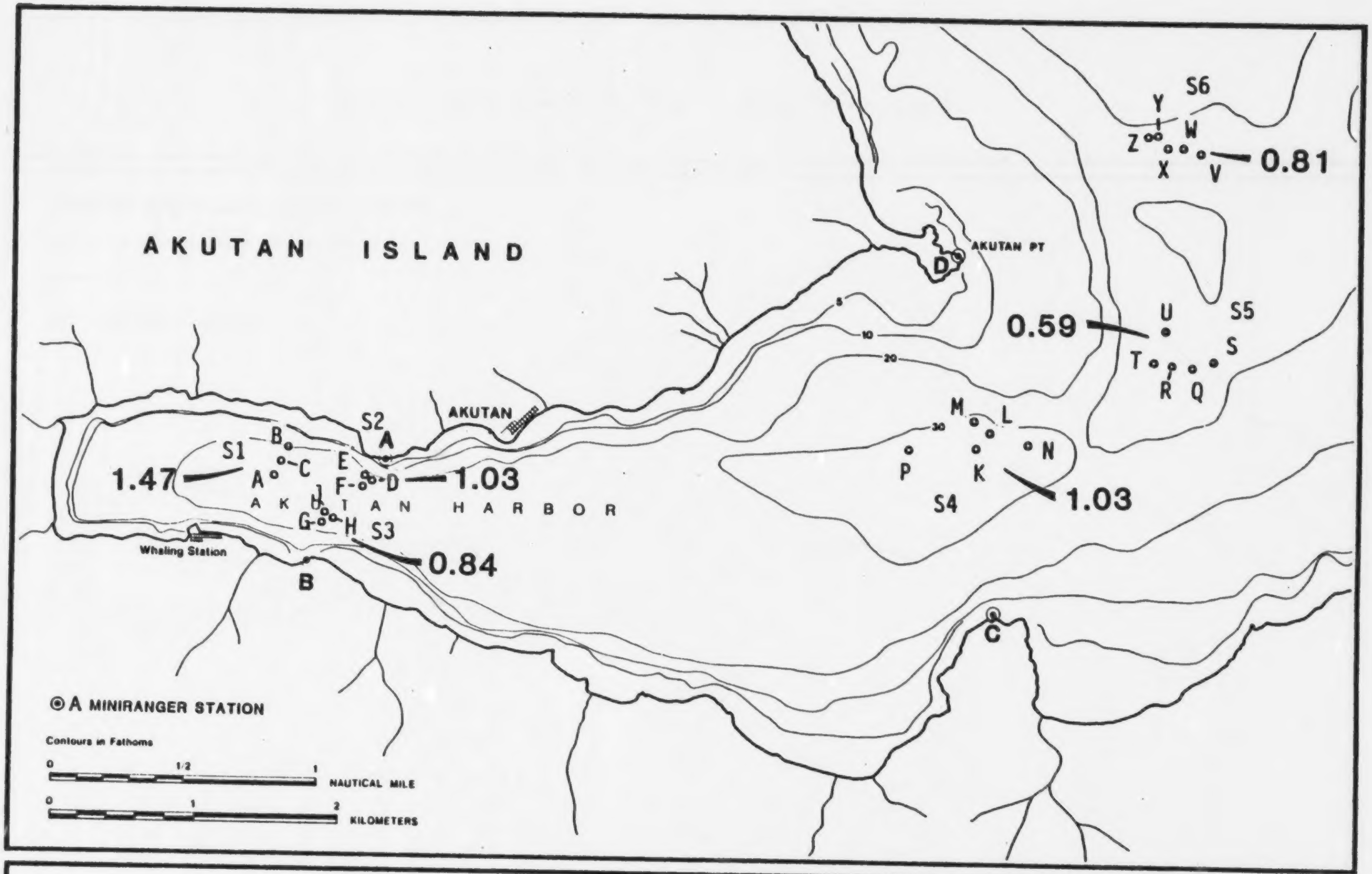

AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
S1
S2
S3
S4
S5
S6
A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
Q
R
S
T
U
V
W
X
Y
Z
1.47
1.03
0.84
1.03
0.59
0.81
5
10
20
30
⊙ A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 22. Total Organic Carbon (%), September 1983

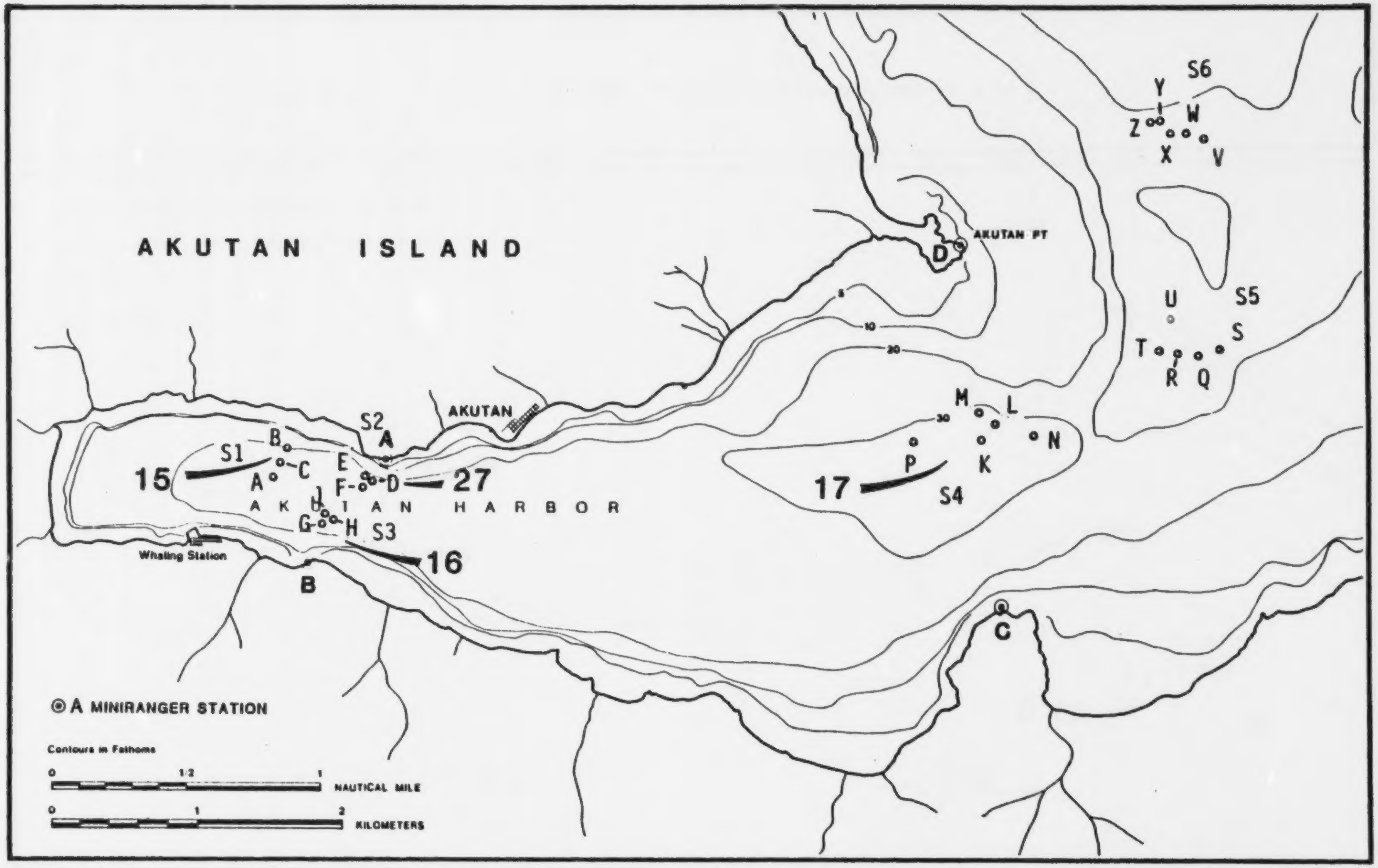

AKUTAN ISLAND
AKUTAN HARBOR
AKUTAN
AKUTAN PT
Whaling Station
◎ A MINIRANGER STATION
Contours in Fathoms
0 1/2 1 NAUTICAL MILE
0 1 2 KILOMETERS
5
10
20
30
S1
S2
S3
S4
S5
S6
15
27
16
17
A
B
C
D
E
F
G
H
J
K
L
M
N
P
Q
R
S
T
U
V
W
X
Y
Z

Figure 23. Ammonia (ppm), September 1983.

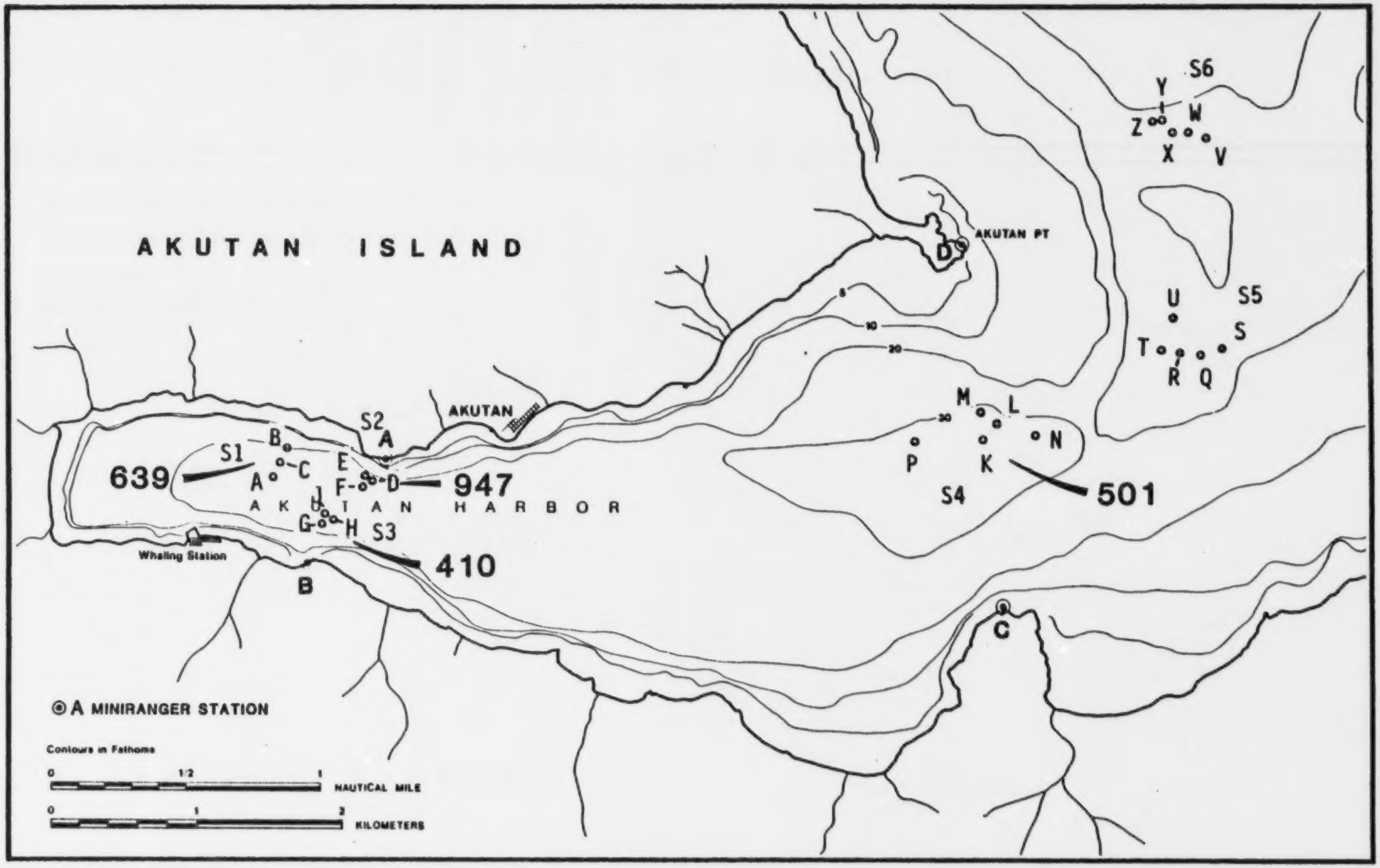

AKUTAN ISLAND
AKUTAN HARBOR
AKUTAN
AKUTAN PT
Whaling Station
639
947
410
501
S1
S2
S3
S4
S5
S6
A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
Q
R
S
T
U
V
W
X
Y
Z
5
10
20
30
A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 24. Organic Nitrogen (ppm), September 1983

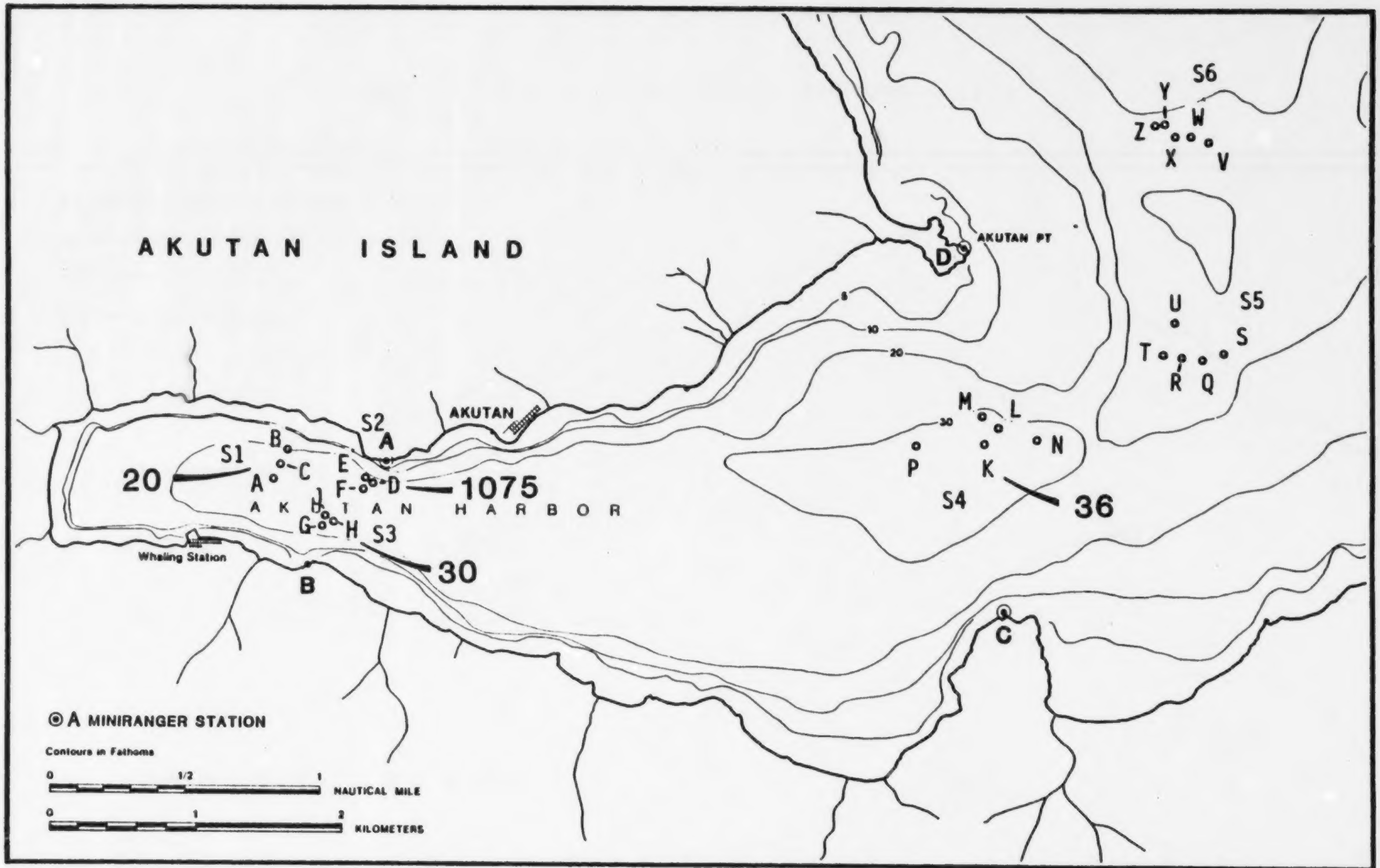

AKUTAN ISLAND
AKUTAN PT
D
AKUTAN
AKUTAN HARBOR
Whaling Station
S1
S2
S3
S4
S5
S6
A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
Q
R
S
T
U
V
W
X
Y
Z
B
C
20
1075
30
36
8
10
20
30
⊙ A MINIRANGER STATION
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS

Figure 25 . Sulfide (ppm), September 1983 that Station 4 was on the edge of a large mound of undetermined age and composition; therefore, this station is included in the discussion of other stations deliberately located on or near waste piles. Sediment Station 19 in Akun Strait (Figure 12, inset) proved to be a hard bottom community. The Van Veen grab collected a softball-sized cobble encrusted by sponges, tunicates, and bryozoans; a small majid crab was also collected. This habitat type was not characteristic of the harbor, and the sample was not preserved.

Sediment Stations 19B-28 were taken on or near the Trident Seafoods waste pile. Stations 19B-21 were taken on a north-south transect across the waste pile, with 19B and 21 presumed to represent the shoreward and seaward margins of the pile, respectively. Stations 22-26 were placed along a transect from the center of the pile to the northwest, along the longitudinal axis of the pile. Station 23 was taken as close as possible to the end of the outfall. Stations 27 and 28 were placed along the longitudinal axis of the pile to the east. Stations 26 and 28 were at the landward and seaward margins, respectively, of the longitudinal axis of the Trident waste pile.

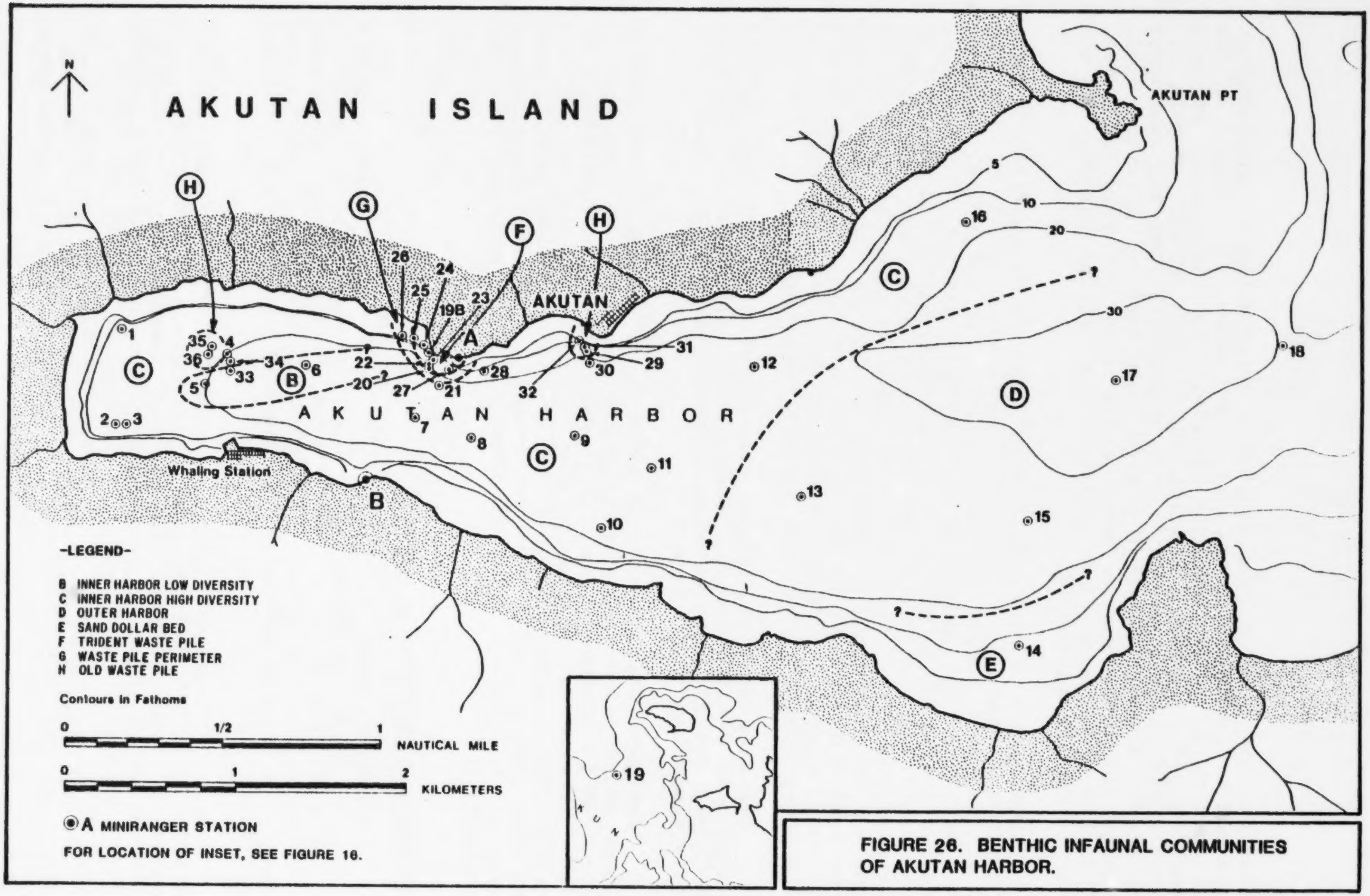
Sediment Stations 29-32 were located on or near an old waste pile off the Akutan Village dock. The floating processor M/V Deep Sea had discharged next to the ship at the dock until 1978 (Soderlund pers. comm.)

Sediment Stations 4 and 33-36 were located on or near a large mound discovered with side-scan sonar and of undetermined age. It is presumed that this mound represents a waste pile on an otherwise homogeneously flat bottom. It is a discrete topographic feature visible on side-scan sonar and located between two permanent mooring buoys. With the exception of Station 4, samples taken on this pile were not analyzed for benthos.

Background Stations in June

The biota found at "background" stations (Sediment Stations 1-3 and 5-18) in June are listed in Appendix G. Although numbers of individuals are provided, these samples should be considered semiquantitative. Replicate samples (necessary for quantitative purposes) were not required for the purpose of the survey in June.

The sediments at background stations were typically brown, stiff silts or fine sands, and did not yield an odor of H_2S. In general, three different "background" communities were identified at depth in the harbor (Figure 26): a community occupying fine (silt/clay) sediments in the inner harbor; a community occupying fine sand in the outer harbor; and a sand dollar community occupying uniform fine sands along the south (exposed) shore of the outer harbor. A fourth community undoubtedly


N
AKUTAN ISLAND
AKUTAN PT
AKUTAN
AKUTAN HARBOR
Whaling Station
A
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1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
19B
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
5
10
20
30
?
-LEGEND-
B INNER HARBOR LOW DIVERSITY
C INNER HARBOR HIGH DIVERSITY
D OUTER HARBOR
E SAND DOLLAR BED
F TRIDENT WASTE PILE
G WASTE PILE PERIMETER
H OLD WASTE PILE
Contours in Fathoms
0
1/2
1
NAUTICAL MILE
0
1
2
KILOMETERS
◉A MINIRANGER STATION
FOR LOCATION OF INSET, SEE FIGURE 18.

FIGURE 26. BENTHIC INFAUNAL COMMUNITIES OF AKUTAN HARBOR.

occupied kelp habitat observed in shallow water south of Akutan Point and along the south shore of the outer harbor.

The most abundant organism in the inner harbor benthic community is apparently *Boccardia* sp., a spionid polychaete. Codominant species (in terms of number of individuals) would appear to be: *Ninoe simpla*, a lumbrinerid polychaete; *Scalibregma inflatum*, a scalibregmid polychaete; and *Macoma moesta*, a tellinid bivalve. Spionid polychaetes are typically opportunistic tube-dwelling forms that tolerate lowered oxygen tensions and feed on organic matter deposited on the sediment surface. Lumbrinerids are free-burrowing forms that tend to be carnivorous. Scalibregmids are active burrowers and feed on detritus found in the sediment (Fauchald and Jumars 1979). *Macoma* spp. typically feed on organic matter deposited on the sediment surface. In general, the species composition at the inner harbor stations (Stations 1-12) indicates recent disturbance and high organic input.

It may be possible to subdivide the inner harbor into two deep water communities, particularly based on species richness. Stations 5 and 6 are distinguishable from Stations 1-3 and 7-12 by the low number of polychaete and molluscan species (Table 12), even though the codominant species are the same throughout the inner harbor. Low species diversity (H', the Shannon-Wiener diversity index, Table 12), together with species composition that suggests disturbance, indicates that Stations 5 and 6 represent an area that may be impacted by adverse water quality or high organic input.

Stations 1-3 are noteworthy background stations in the inner harbor because of the heterogeneity of the sediments. Station 1 was located off the mouth of the largest freshwater stream draining into Akutan Harbor. The first sample taken at this station was rejected because a small pebble had lodged in the jaws, resulting in a loss of some material. The sediment apparently included alluvial sands. High detritus input to the sediment at Station 1 is indicated by the presence of *Echiuris echiuris* (=*E. alaskanus*). This small sac-like worm (Phylum: Echiura) feeds on organic detritus that settles on a spoon-like proboscis extended on the sediment surface. Stations 2 and 3 were located near the moored floating processor M/V *Deep Sea* (Plate 4). Station 2 sediments included gravel material, and Station 3 included a low-density material resembling pumice or perhaps coal cinders. The heterogeneity of the sediments at these three stations may be either highly localized, resulting from stream discharge or human activity, or may be characteristic of the benthic community at the extreme head of the harbor. Although sediment heterogeneity often increases species diversity or species composition, this did not occur at these three stations (Table 12).

The benthic community in the silty sand of the outer harbor (Stations 13, 15, 17-18) displays similarities as well as

Table 12. Number of Species and Codominant Species at Each Station in June

Number of Area and Station No.	Species	H'	Codominant Species
Inner harbor low diversity			
5	7	1.74[1]	*Boccardia*/*Scalibregma*
6	4	0.70	*Boccardia*
Inner harbor high diversity			
1	18	2.70	*Boccardia*/*Macoma moesta*
2	16	2.21	*Boccardia*/*Macoma moesta*/*Ninoe*
3	15	2.58	*Boccardia*/*Laonice*/*Ninoe*
7	16	2.69	*Boccardia*/*Macoma moesta*
8	15	2.63	*Boccardia*/*Ninoe*/*Scalibregma*
9	13	2.47	*Boccardia*
10	25	3.02	*Boccardia*/*Macoma moesta*/*Ninoe*
11	14	2.19	*Boccardia*/*Prionospio*/*Axinopsida*
12	22	3.00	*Boccardia*/*Prionospio*
16	25	3.61	*Boccardia*/*Ninoe*
Sand dollar bed			
14	15	2.12	*Boccardia*/*Echinarachnius*/*Euclymene*
Outer Harbor			
13	10	2.84	*Prionospio*/*Ninoe*/*Macoma moesta*
15	16	3.00	*Ninoe*/*Macoma moesta*
17	20	3.35	*Euclymene*/*Boccardia*/*Ninoe*
18	26	4.20	*Axinopsida*/*Travisia*/*Ninoe*
Trident waste pile			
19B	5	0.56[2]	*Boccardia*
20	1	—[2]	—
22	2	0.81	*Axinopsida*
24	1	0.00	—
27	2	1.00	—
Waste pile perimeter			
21	17	2.66	*Scalibregma*/*Boccardia*/*Macoma moesta*
26	3	0.06[2]	*Boccardia*/*Echiuris*
28	10	2.36	*Boccardia*/*Prionospio*
Old waste pile			
29	14	0.77[2]	*Boccardia*/*Echiuris*/*Prionospio*
30	12	1.77	*Boccardia*/*Echiuris*/*Prionospio*
31	18	1.99	*Boccardia*/*Echiuris*/*Prionospio*
32	15	0.96	*Boccardia*/*Echiuris*
4	18	3.12	*Boccardia*/*Scalibregma*/*Ninoe*

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[1] H' calculated to base 2.

[2] Unquantified taxon not included (see Appendix H).

differences relative to those found in the fine sediments of the inner harbor. For example, Boccardia sp. is present in the outer harbor community, but is not the most abundant organism and may not even be a codominant species (with the possible exception of the shallow basin around Station 17). The codominants at the stations of the outer harbor appear to be Ninoe simpla (Lumbrineridae) and Macoma moesta. Species diversity (H', Table 12) may also be greater in the outer harbor due to a more even distribution of numbers of individuals over the taxa present (Appendix G), compared to inner harbor stations.

A unique community occurred in Station 14, apparently as a result of sampling in a sand dollar bed. Although this station was occupied by only 15 species, it contained more crustaceans (individuals and species) than any other station. Constant reworking of the uniformly fine sands by the sand dollars, and perhaps by waves off the Bering Sea, may have resulted in fewer species (especially numbers of polychaete species) relative to Station 10, which occurred in silty sands near the south shore.

Stations on or Near Waste Piles in June

Biological sampling was conducted on or near the Trident waste pile (Sediment Stations 19B-28), near an old waste pile (Sediment Stations 29-32), and near a pile of undetermined age (Sediment Station 4). Additional visual observations (Sediment Stations 33-36) were made on the pile near Station 4. The biota found on or near waste piles in June are listed in Appendix H.

Trident Waste Pile. The Trident waste pile is composed primarily of codfish wastes, and secondarily of wastes from crab, herring, and other species. The longitudinal axis of the impacted area is apparently oriented parallel to the shoreline around the obtuse angle formed by the bulkhead, but the bulk of the material is located as a pile on the outfall (Sediment Station 23).

Station 19B was placed as close to the bulkhead as possible. The sample consisted primarily of quantities of black granular material, garbage, and fish wastes. It smelled of H_2S, and gave off an oil-like sheen when subsampled. Stations 20, 22-25, and 27 were clearly located on the waste pile, and revealed little biota (Appendix H, Table 12, Plate 5). Station 23 was located as close as possible to the outfall. When brought to the surface, the material degassed (H_2S and perhaps methane, CH_4) and boiled out of the screens on the top of the Van Veen grab (Plate 6). No sample was preserved at this station. Samples at remaining stations on the waste pile were typically anoxic, comprised of grainy black material, recognizable bone fragments, pieces of fish tissue, and a strong H_2S odor. Station 25 was taken in an effort to sample the northwest edge of the waste pile; however, the sample appeared no different from that of Station 24 and was not preserved.

Stations 21, 26, and 28 were taken in an effort to sample the biota near the waste pile. It would appear from the biota and species richness that Station 21 is similar to background conditions, i.e. dominated by *Scalibregma*/*Boccardia*/*Macoma moesta* (Table 12). However, the station clearly was influenced by the waste pile because of an anoxic layer below the top 3-4 cm of brown sandy silt. The sample had a slight odor of H_2S combined with an "organic" smell. Station 26 displayed low species richness and a thin layer of aerobic sediment over anoxic muds, but was unusual in the presence of a few juvenile *Echiuris echiuris* (=*E. alaskanus*). Station 28 showed little evidence of impact (Appendix H); with the exception of the absence of bivalves, faunal composition at Station 28 was similar to that found at Stations 7-12 (Appendix G).

Preliminary underwater television camera work in June revealed that pelagic crustacean species occurred in the water column over the Trident waste pile, but bottomfish and epibenthic invertebrates were absent from the pile. All of these organisms were commonly seen elsewhere in the harbor. Crabs were most abundant near the waste pile.

Old Waste Pile. The waste pile off the Akutan Village dock theoretically had not received crab wastes since 1978, but probably received low input of miscellaneous garbage off the dock, the M/V *Western Sea*, and fishing vessels as they offloaded catches to the M/V *Western Sea*. Crab wastes were noted at Stations 29 and 31. The wastes were clearly old; the exoskeleton had demineralized and the remaining chitin matrix was very pliable. The sediments at Stations 29 and 30 were dark brown and sandy, whereas the materials at Stations 31 and 32 were black and anoxic.

The biological community associated with this waste pile contained species approximately similar to those found in background conditions at Stations 7-12. A major difference was the abundance of *Echiuris*, especially juveniles (Appendix H). Furthermore, most of the rare species (found only once at one station) associated only with waste piles were found here (Appendix I).

Inner Harbor Waste Pile. Stations 4 and 33-36 were located near or on a large mound between two permanent mooring buoys in the inner harbor. Stations 4, 33, and 34 were near or at the edge of the mound and did not appear to be different from background conditions. Sediment grain size visually (4, 33, 34) and analytically (Station 4 only) was comprised primarily of fine brown silt or clay. The biota from Stations 33 and 34 appeared similar to that of Station 4 (Appendix D). Station 35, located near the apex of the pile, contained dark sediments and a soapy, sludge-like gray material with scattered aggregated materials similar to those associated with corroded metals. Station 36 was located on the apex of the pile, and consisted of medium sand. Bivalves and polychaetes were observed. Clinocardium sp., typically associated with sandy substrate, was also observed at Station 36.

Biological Community - September 1983

Six stations (3 inner harbor and 3 outer harbor) were sampled in September 1983. Sampling locations correspond to September sediment stations (Figure 20). Species collected at these stations are listed in Appendices J, K, and L.

Stations S1, S2, and S3 are inner harbor stations approximately corresponding to June Sediment Stations 6, 20, and 7, respectively. Three replicate grabs were taken at each of these stations. Stations S4, S5, and S6 are outer harbor or Akutan Bay stations; five replicate grabs were collected at these stations. Station S4 corresponded to June Sediment Station 17 in the outer harbor. Stations S5 and S6 in Akutan Bay were sampled to characterize the benthic community at possible solid waste disposal sites for the City of Akutan.

Inner Harbor Stations

Station S3 was occupied in September as a representative of an inner harbor "background" area generally characterized as having a high diversity community in June. Species richness (17, 18, and 23 species) in three separate grabs taken in September (Table 13) reflects that seen in June (Table 12). The community was numerically dominated by the polychaetes Ninoe simpla and Boccardia polybranchia.

Station S2 was on the edge of the Trident waste pile, between June Stations 20 and 21. Species richness was lower than at the background station; only 7, 8, and 12 species were found in the separate grabs (Table 13). This community was also numerically dominated by polychaetes; especially Capitella species A. Overall abundance was low except for Capitella, which was more abundant here than at any other site. The sediments at this station were black and exhibited few surface burrows. High numbers or high biomass of Capitella spp. is often taken as an indicator of high organic pollution, as might be expected in the vicinity of the waste pile.

Station S1 was off the waste pile at a distance approximately equal to that of S3, but the area was characterized in June by low diversity. In September, species richness at this station was not distinguishable from background stations (Table 13). The polychaetes Prionospio steenstrupi and N. simpla and the bivalve Macoma moesta numerically dominated this

Table 13. Number of Species and Numerically Dominant Species at Each Station in September

Area[1] (Station) & Sample No.	Number of Species	H'	Codominant Species
Inner harbor low diversity[1] (S-1)[2]			
A	20	3.55[5]	Ninoe/Boccardia/Axinopsida
B	18	3.16	Prionospio steenstrupi/Macoma moesta
C	13	2.45	Ninoe/Scalibregma
Inner harbor high diversity (S-3)[2]			
G	17	2.82	Boccardia/Ninoe
H	18	3.66	Ninoe/Boccardia/Axinopsida
J	23	3.76	Ninoe/Scalibregma
Waste pile perimeter (S-2)[2]			
D	12	3.02	Boccardia
E	7	1.18	Capitella sp. A
F	8	2.75	Nereis zonata/Scalibregma
Outer harbor (S-4)[3]			
K	24	4.14	Ninoe/Macoma moesta[4]
L	31	3.93	Mediomastus/Ninoe
M	27	3.45	Prionospio steenstrupi[4]
N	23	4.09	Macoma moesta
P	27	4.25	Macoma moesta/P. steenstrupi/Axinopsida
Akutan Bay (S-5, S-6)[3]			
Q (S-5)	28	4.35	Axinopsida/Macoma moesta
R "	30	4.33	Axinopsida/Harpinia/P. steenstrupi[4]
S "	33	4.08	Mediomastus/Macoma moesta/Axinopsida[4]
T "	28	4.01	Ninoe
U "	43	3.72	P. steenstrupi/Axinopsida/Mediomastus[4]
V (S-6)	24	4.09	Nuculana
W "	31	4.34	Axinopsida/Macoma moesta/Ninoe[4]
X "	27	3.93	P. steenstrupi/Nuculana/Harpinia[4]
Y "	23	4.22	Axinopsida/Mediomastus
Z "	27	3.98	Mediomastus/Macoma moesta[4]

---

[1] Area designations correspond to June designations (Table 12)

[2] Sieved with 1-mm mesh screen

[3] Sieved with 0.5-mm mesh screen

[4] Nematodes in fine (0.5-mm) portion

[5] H' calculated to base 2.

area. There are other indications, however, that Station S1 in September was still different from background conditions (Station S3). Several of the species at Station S1 were represented only by juveniles. This suggests a recent increase in species richness in this area. A subjective comparison of biomass suggests that bivalve biomass is measurably higher at Station S1, whereas polychaete biomass is measurably lower at Station S1 (Table 14). At Station S1, Sample C appears to have the lowest values in the several parameters included in Table 14. It appears, therefore, that inner harbor communities as identified by June data (Figure 26) are probably applicable to September observations.

Outer Harbor and Akutan Bay Stations

Station S4 was in the vicinity of June outer harbor background Station 17. The five grabs at this station had 23, 24, 27, 27, and 31 species (Table 13). Abundance was also generally high. The macrofaunal community was numerically dominated by M. moesta and the polychaetes P. steenstrupi and N. simpla. Nematodes also appear as dominants if contents of the 0.5-mm mesh sieve are included in the analysis. The 0.5-mm mesh sieve also retained large quantities of algal fragments. This detrital material probably originated in the kelp beds that occurred in the area along shore in June, but to a greatly reduced extent in September.

The stations identified as possible ocean dumping sites for incineration wastes from the Village of Akutan (S5 and S6) were similar to Station S4 in general species richness and abundance. Station S5 had especially high species richness (Table 13) and abundance (550 total individuals). The macrofauna was numerically dominated by the deposit-feeding bivalve Axinopsida orbiculata and the polychaetes P. steenstrupi and Mediomastus capensis. Nematodes were abundant in the material retained by the 0.5-mm sieve.

To a certain extent, higher species richness at Stations S4-S6 occurs because inner harbor stations (S1-S3) were handled differently from the outer harbor stations (S4-S6). Inner harbor stations were sieved with 1-mm mesh, while outer harbor stations were sieved with 0.5-mm mesh. On the other hand, some real differences occur between these two areas. The macrofauna of the inner harbor were in all cases numerically dominated by polychaetes. The outer harbor stations tended to be dominated by bivalves (either M. moesta or Axinopsida); polychaetes were less dominant. A number of species unique to the outer harbor or Akutan Bay were also noted (Appendices J and K). For example, sea whips (a soft coral) were collected in Akutan Bay; they also were frequently observed in the video camera transects through the outer harbor, but not in the inner harbor. These

Table 14. Comparison of Stations S1 and S3 in September.

	H'	POLYCHAETES			BIVALVES	
		BIOMASS*	# SPECIES	# INDIVIDUALS	# SPECIES	# INDIVIDUALS
Station S1						
A	3.55	0.74g	12	47	5	26
B	3.16	0.74g	11	47	5	24
C	2.45	0.29g	9	32	2	5
Station S3						
G	2.82	3.27g	11	63	6	13
H	3.66	1.15g	11	43	6	14
J	3.76	1.35g	21	63	2	7

---

* Wet weight preserved in alcohol

differences in community composition likely reflect habitat differences between the areas.

CONCLUSIONS

The purpose of this investigation was to describe flushing characteristics and assess the possible impacts of seafood waste deposits on the water quality, sediments, and biological community of Akutan Harbor.

Flushing Characteristics

The flushing characteristics or residence time of marine embayments is a primary consideration in evaluation of potential impacts of wastewater discharges. At steady state, the mass of wastewater accumulated in the embayment is approximately equal to the wastewater mass discharged during the residence time period. For example, if the residence time is 7 days, the steady state total mass of wastewater distributed throughout the embayment would be approximately equal to 7 days of discharged waste. Particles discharged with the wastewater are not flushed from an embayment in the same manner since they are subject to settling within the bay.

Flushing is commonly defined as the action of gradual replacement of "old" water inside an estuary (or embayment) with "new" water originating outside of the estuary. Flushing is governed by two basic processes: dispersion (diffusion) processes, and advective processes. Advective processes are the predominant mechanisms controlling flushing action, and can be approximately categorized by the following three processes:

1. Fresh water outflow
2. Tidal advection
3. Wind driven and/or geostrophic circulation.

Estuaries that receive a significant amount of fresh water flow relative to the average water volume of the estuary experience a net movement of water through and out from the estuary which carries pollutants along with it and results in a direct flushing mechanism. Estuaries that have a large tidal prism (i.e., on the order of 30 percent or greater of the average water volume) experience significant flushing indirectly through the continuous oscillatory motion of the tidal waters and eventual exchange with water originating outside the boundaries of the estuary.

Akutan Harbor does not benefit significantly from either of the above two flushing mechanisms. The third type of advective/flushing mechanism, i.e., wind-driven and/or geostrophic circulation, is the predominating flushing mechanism within Akutan Harbor. The size of Akutan Harbor likely precludes significant flushing by geostrophic circulation, therefore, wind-driven circulation is likely the most important advective process. This phenomenon is also the most difficult to assess accurately since the forcing mechanisms are erratic and the resulting circulation patterns can be very complex.

Based on the June results, it is possible to estimate an approximate residence time of a water particle released near the Trident seafood processing plant outfall during a sustained 15 knot east wind event. Assuming an average surface layer velocity of about 2.5 cm/lsec for the layer 0 to 13 m (toward the west) and an average bottom velocity of about 1.0 cm/sec for the layer 13 to 38 m (toward the east), the residence time of a surface water particle at the trident outfall would be approximately 5.5 days, and the residence time of a water particle released in the bottom layer at the Trident outfall would be approximately 2.5 days.

It is emphasized that the above flushing calculations assume a steady-state 15 knot wind from the east. This condition represents a "best case" for flushing in that circulation under these conditions results in net bottom currents moving out of the harbor. In actuality, however, sustained easterly wind events are not the norm for this area. According to the NOAA climate atlas, wind direction statistically is evenly distributed from all directions with easterly wind events (NE, E, SE) occurring approximately 30 percent of the time. Easterly wind events that are of sufficient strength and duration to create a steady-state type circulation (as observed during the June survey) probably occur much less than 30 percent of the time, however. It is certain, therefore, that the residence time at the Trident outfall is significantly greater than the 5-6 days estimated for a sustained, 15 knot easterly wind event.

The observed movement of the drogues in September was only partially in response to wind circulation. After 1600 on September 17, when winds subsided, circulation induced by flow patterns in Akutan Bay was probably responsible for the observed drogue motion.

To infer a harbor flushing or residence time from September drogue data is difficult due to the large variations in wind conditions and the complexity of the drogue movements. The large temporal variations in wind conditions create an unsteady circulation pattern that defies representation by any known analytical model. A qualitative description of circulation patterns, however, can be inferred from the drogue movements. It is apparent that Akutan Harbor is composed of inner and outer circulation regimes. The boundary between these regimes is not exact, but is approximately located along a line drawn south from the town of Akutan. This corresponds to the area at which the width of the harbor begins to increase rapidly to the east. In general, drogues released inside (west of) this line tend to meander and/or move inward toward the head of the harbor.

Drogues released outside (east of) this line tend to move more rapidly and in a general counterclockwise manner, thereby inferring the existence of a large-scale gyre in the outer portion of the harbor. Drogues observed during the June survey exhibited the same general behavior in the outer harbor. This gyre (eddy) is probably caused by the larger scale circulation in Akutan Bay and through Akun Strait. The effect of these large eddies on the harbor would be to generally increase the flushing rate in the outer harbor, i.e., a water particle originating near the south shore of the harbor would tend to be carried outward toward Akutan Bay where it has a greater chance of being carried away by the external currents.

Based on an evaluation of September drogue movements, the residence time of the harbor appears to be longer than the 2.5 to 5.5 days estimated from drogue motion observed during persistent winds from the east in June. This is because the 20-m and 30-m drogues did not leave the harbor over an approximately 48-hr period. The residence time of deeper water under conditions of circulation induced by Akun Strait only (no wind) may be on the order of a few weeks. The surface layer, as indicated by the 10-m drogues, appears to have a shorter residence time than the deeper layers. Two shallow drogues, #5 and #17, were advected out of the harbor in less than 24 hours. Sustained winds from the east (as observed in June) may represent the worst case for surface layer flushing and a best case for flushing of deeper water. Again it must be emphasized that circulation in Akutan Harbor, and therefore the residence time, will be highly variable because of the importance of wind on harbor circulation.

It is cautioned that the fraction of freshwater method is relatively crude, especially when the ratio of freshwater inflow to harbor volume is very small. An estimate of 177 days, obtained by using this method, is very approximate. There are several factors that must be considered in evaluating this estimate. First, it is based on a June freshwater inflow estimate of 64 cfs. It is not known how this compares to total freshwater input during the approximately 177 days prior to the September observations on salinity structure. Stream runoff is primarily influenced by precipitation patterns (Stepetin pers. comm.). The June data were taken at a time when some snowpack was still present, but rainfall was not a major contributor. Second, groundwater input to the harbor is possible, particularly from the valley at the head of the harbor. Although this may contribute to the observed salinity structure of the harbor, its significance is unknown because no data are available on quantity. Third, precipitation falling directly on the harbor will contribute to salinity structure, particularly if easterly winds tend to trap surface water in the harbor.

Although calculations from drogue data and salinity structure are not conclusive, the data indicate that residence time of water in Akutan Harbor is measured in weeks. The salinity structure observed in September integrates best (sustained easterly winds $\geq$ 15 knots) as well as worst (calm air) conditions during the previous weeks. If it is assumed that the volume of freshwater inflow used in the calculations is as much as either twice or half the actual value, the residence time would range from 88 to 354 days.

Currents in the inner harbor are not adequate for resuspension of deposited wastes. Assuming that all particles are ground to 1.27 cm (0.5 in) or less and that the specific gravity of flesh is approximately 1.03 to 1.06, a current velocity of 15-20 cm/sec is necessary to set deposited particles in motion (Wennekens pers. comm.). Drogue data indicate that current speeds in the inner harbor are significantly less, perhaps by as much as an order of magnitude, even during sustained easterly winds.

Water Quality

Previous water quality sampling of Akutan Harbor consisted of two separate water quality studies that occurred in May: EPA and ADEC (1978) and ADEC (1982). These reports indicate generally good water quality. Discussion of these analyses was presented in the draft Reconnaissance Report: Water Quality Assessment of Akutan Harbor, Alaska (Jones & Stokes Associates 1983), and will not be presented in this report.

The data collected in June and September 1983 indicate that the harbor was well mixed and oxygenated. A variation in ammonia concentration between the inner and outer harbor in June was observed in the water column, but cannot be linked at this point to seafood waste discharge or the occurrence of waste deposits.

The water quality parameters measured did not indicate a detrimental impact from seafood waste piles. Elevated nitrogen compound concentrations above the Trident Seafoods waste pile are indicative of a flux between the waste pile and the water column. The anoxic condition of the waste pile in contrast to the high dissolved oxygen concentration directly above the waste pile leads to the conclusion that the rate of oxygen transfer to the waste pile from the water column is significantly less than the oxygen transfer within the water column. This relationship would vary if stratification occurs during the summer and the lower layer becomes relatively stagnant. Nitrogen concentrations may also increase under the above conditions. Water column stratification was not evident in September, however, indicating that summer stratification in Akutan Harbor is temporary or absent.

No water samples were collected in a discharge plume or during discharge because processing activity was absent or at a low level during the field work. These data were to have been provided to EPA by Trident Seafoods as a requirement of a Clean Water Act Section 309 order. The data have not been provided. It is likely that locally adverse water column conditions occur as the effluent discharges through the anoxic waste pile on the Trident outfall. Hydrogen sulfide, ammonia, and suspended and dissolved organic matter from the waste pile are probably entrained in the discharge plume. During water column circulation established by sustained easterly winds, the effluent plume most likely moves westward and southward in a counterclockwise direction. During quiet water conditions, the effluent plume most likely meanders in the inner harbor area.

The waste discharges have violated Alaska Water Quality Standards (ADEC 1979). No mixing zone has been established for the Trident outfall. The effluent results in the deposits of solids on the bottom. State standards prohibit solids accumulation in marine waters classified for use in: seafood processing; growth and propagation of fish, shellfish, aquatic life, and wildlife; and harvesting raw molluscs or other raw aquatic life for consumption. This prohibition also applies to marine waters classified for contact and secondary recreation.

Sediment

Akutan Harbor has fairly steep sides sloping to a generally flat bottom between 35 and 55 m deep. Small alluvial fans have formed at the mouths of many of the streams, and have created locally shallow nearshore areas. Large-scale sand waves were detected in Akutan Bay, but not in the harbor (west of Akutan Point). The analysis of the top few centimeters of sediments showed that the bottom sediments in the inner harbor have a higher percentage of fines and that the percent of sand increases toward the outer harbor. These findings indicate that the inner harbor is more protected than the outer harbor, and that scouring and dispersion capabilities are apparently absent in the inner harbor.

Higher ammonia-nitrogen levels in June in the outer harbor relative to inner harbor sediments are not easily explained. Typically, one would expect higher ammonia-nitrogen in the finer sediments, especially near decomposing seafood waste piles. It is possible that relatively low organic carbon in the outer harbor may be limiting to nitrification, and this may account for higher ammonia concentration in the outer harbor. Total organic carbon (TOC) data support this possibility; TOC levels were as much as an order of magnitude greater in the inner harbor during June. Thus, more carbon was available for nitrifying bacteria in the inner harbor, resulting in decreased ammonia concentrations, even though inner harbor sediments are finer.

Seafood waste accumulations on the bottom sediments were detected at six locations, as discussed in the side-scan sonar results section. The accumulation of wastes has a major impact on the physical and chemical characteristics of sediment near an outfall. The surface sediment layer is totally covered by waste in areas with large depositions. Along the edges of a waste pile some mixing of the wastes with the sediment may occur. Increases in TOC, ammonia, and grain size were found near and on the waste piles sampled, and probably result from the waste discharge and subsequent decay.

In September the sediment sampling showed a significant difference between the station located near the Trident waste pile (S2) and other stations. High levels of sulfide, ammonia, TOC, and organic nitrogen indicate the presence of fish waste and anaerobic decomposition at this site. The amounts of toxic hydrogen sulfide and un-ionized ammonia are both functions of pH; the lower the pH, the higher the ionization. Temperature is also a factor in ammonia speciation. Criteria for ammonia and sulfide have been established for water by EPA (1976). Based on sediment data, both criteria would be exceeded for all stations if the total amounts measured were dissolved in the pore water of the sediment. However, a large percentage of ammonia and sulfide are probably bound to particles and are not dissolved in the pore waters. This would decrease the concentration and resultant toxicity of sulfide and un-ionized ammonia.

A correlation analysis between the sediment parameters in September shows a positive correlation between sulfide and nitrogen (ammonia and organic nitrogen); however, no correlation was found between sulfide and TOC. High TOC levels therefore are not sufficient to indicate anoxic sediments.

September data revealed no major differences between inner harbor and outer harbor sediment chemistry. This is in contrast to June data. There are two major factors that may account for the observed similarities in September. First, Trident discharges occurred until just prior to the June survey. Destruction of the plant by fire in June eliminated these discharges during the months prior to the September survey. Organic input from this source to the inner harbor was significantly lower during the period prior to the September field work. Second, extensive die-off of kelp beds near Akutan Point and along the south shore of the outer harbor resulted in significant input of detrital material to outer harbor sediments. Either factor alone could account for the observed differences between June and September sediment chemistry.

Biological Data

It is self-evident that persistent waste piles on the harbor floor kill biota beneath them. It is unclear how far from the piles benthos will be impacted, and what period of time is necessary for the benthos community to return to pre-discharge conditions.

Evidence from Akutan Harbor indicates that the waste piles are discrete units that apparently retain their integrity for a great length of time, i.e., do not disperse. Old wastes off the Akutan Village dock were still apparent as a pile 5 years after discharge is presumed to have ceased. A waste pile of indeterminate age in the inner harbor (June Sediment Stations 4, 33-36) retained a sharp profile, but was apparently aged sufficiently such that an aerobic outer layer, and no recognizable crab parts, were visible. Cod wastes on the Trident waste pile, although near neutral buoyancy, remained as a cohesive pile on a relatively steep slope. Observations with an underwater TV camera indicated that the edge of the pile was remarkably narrow, i.e., complete waste cover gave way to clear bottom within only a few meters. There was no evidence that relatively fresh codwaste occurred anywhere other than as a pile over the Trident outfall.

In addition to the area of the waste pile, it is evident that the biota near the edge of the waste piles are impacted. The magnitude and areal extent of the impact vary, depending on the distance and direction taken from the waste pile. For example, Sediment Station 21 in June was comprised of anoxic muds below an aerobic surface layer, but the biota living in the aerobic layer were not much different from background conditions. Biota at Sediment Station 27 were clearly impacted, whereas biota and sediment conditions at nearby Station 28 were very similar to background conditions. Compared to background stations, species richness was significantly lower in June in an area extending for some distance to the southwest of the Trident pile (Stations 5 and 6, Figure 26). This area showed signs of recovery in species richness in September (Station S1, Table 13) but other observations on the fauna (Table 14) indicate conditions continued to be different from those at a background station (S-3) in September.

A difficult question is whether background conditions in Akutan Harbor are indicative of impact on benthic community structure. The seasonal occurrence of floating processors in the inner harbor results in periodic deposition of organic wastes throughout the inner harbor. The polychaetes throughout the inner harbor are typically associated with high organic input and occasional bottom disturbance. The dominant species in inner Akutan Harbor are similar to those found within a kilometer of waste outfalls at Dutch Harbor (Feder and Burrell 1979) and Cordova (Caponigro 1979), but outside of areas receiving waste deposits. At Cordova, a similar benthic community occupied a waste outfall site in a well-flushed area that had not received waste discharges for a year.

Sediment and biological data from June indicate that anaerobic sediments occur parallel to shore in both directions from the waste pile over the Trident outfall. These areas are probably impacted as a result of tidal movements, particularly during calm weather and the absence of wind-generated currents.

It is likely that the benthic community extending to the southwest of the Trident outfall has also responded to the waste discharge. Several pieces of evidence together support this observation. Modelled water current and flushing patterns indicate that a southwesterly flow of the discharge plume from the Trident plant is likely during sustained easterly winds. Circulation in the inner harbor is driven by wind; winds from other directions may not be adequate to set up a circulation pattern in the inner harbor that carries the plume in other directions. TOC and organic nitrogen in the sediments are higher to the southwest of the Trident waste pile (Sediment Stations 5, 6, or S1) than directly to the south (Sediment Station 7 or S3). Soon after cessation of discharge (June), species richness to the southwest of Trident was low; however, 4 months after cessation, species richness apparently was recovering. This indicates that the benthic community is affected by the Trident discharge plume directly, or by the plume after it percolates through the waste pile. The waste pile alone may not be impacting this area, because the pile could not have changed significantly in 4 months. Whether the benthic community to the southwest of Trident is responding to settling solids, high BOD, or dissolved sulfide or ammonia in the plume cannot be determined until the discharge plume is sampled during circulation patterns induced by easterly winds.

Case Study - Dutch Harbor

Major seafood processing activity occurs in the vicinity of Dutch Harbor on Unalaska and Amaknak Islands, part of the eastern Aleutian Island chain of Alaska. This area is well known for its seafood processing of king crab, Tanner crab, Dungeness crab, and shrimp. Over 70 million pounds of shellfish were processed during the 1976 season and resulted in approximately 47 million pounds of wastes that were disposed of mainly by discharge into the adjacent bays (Karna 1978). The effects of seafood processing and waste disposal within this general area have been studied extensively.

Several investigators have documented the build-up of processing wastes around the points of discharge (U.S. Fish and Wildlife Service 1982, Bechtel 1979, Feder and Burrell 1979, Karna 1978). Factors affecting the fate and amount of waste build-up include compaction and slumping, microbial degradation, downslope movement, and dispersion. The location of the outfall with respect to local wave and tidal currents plays a significant role in the amount of waste accumulated. Brown and Caldwell (1978, 1979, 1980) has conducted performance studies on nearshore outfalls versus deep water outfalls (over 7 fathoms) at Dutch Harbor. The nearshore environment was more energetic and resulted in greater waste dispersion. As a result, nearshore outfalls displayed limited waste accumulations (within NPDES permit limitations), no beach accumulation, no hydrogen sulfide detected, and complete dispersion of accumulated wastes during winter storms. Problems identified with deep water disposal include little dispersion of wastes, anoxic conditions within the waste pile, and the associated production of hydrogen sulfide.

Benthic biota were found by investigators to be eliminated within the area of waste deposition (Karna 1978, Feder and Burrell 1979), either due to suffocation from burial or anoxic condition. Documentation of the effect of waste piles in Dutch Harbor on biota near the pile perimeters and on motile epifauna has been contradictory. Feder and Burrell (1979) found that the biota near deposition areas were reduced in diversity and stressed. Bechtel (1979) found evidence that motile biota were attracted to the waste piles as a food source. They suggested further study on the beneficial aspects of the increased food supply on the biota.

The water quality of the inner bays, Dutch Harbor and Iliuliuk Bay, is affected by natural summer and fall water column stratification and resulting anoxic conditions in the lower waters. The discharge of processing wastes no longer occurs in this region to prevent aggravation of natural water quality problems (Brown and Caldwell 1978). The majority of the processing wastes are now discharged to the western side of Amaknak Island. Due to the current velocities at these sites little impact on the quality of the water column is observed (Bechtel 1979), although anoxic conditions are found within the waste piles. Hydrogen sulfide is produced during decomposition and can be detected within and sometimes just above the waste piles.

Comparison with Akutan

Both Dutch Harbor and Akutan receive large quantities of seafood processing wastes, although very little, if any, codfish processing occurs at Dutch Harbor. Both crab and cod wastes exert a large oxygen demand during decomposition. Wastes tend to accumulate near discharge points because the rate of discharge during processing is greater than the decomposition rate. Comparison of physical conditions at Dutch Harbor with those of Akutan leads to the following:

1. Water column stratification in the fall is a common feature in the Aleutian Islands (Reeburgh pers. comm.), but no stratification was observed during the September investigation at Akutan. Dutch Harbor is unlike Akutan in that comparatively shallow sills separate deeper basins in the Dutch Harbor area, thereby exacerbating stratified water circulation and anoxic conditions at depth. The biological community at Akutan near the waste piles is obviously affected by anoxic conditions in the nearby waste; however, the biota at Akutan inner harbor is not like that in Dutch Harbor and Iliuliuk Bay

where anoxic conditions are common in the deeper water. It is not clear whether adverse water quality will occur in the water column at Akutan as waste piles continue to accumulate.

There is evidence from sediment chemistry and biota that a plume may occur to the southwest of the Trident discharge. The hydrologic modelling suggests that this plume may occur only when inner harbor water is induced to circulate by east winds. It is not clear whether adverse water quality will occur in the inner harbor during discharge when wind patterns are not inducing movement of inner harbor water.

2. During fully-mixed conditions when no discharge is occurring, the circulation in Akutan Harbor is sufficient to flush the water column but not to remove the waste piles. Waste piles eliminate benthic life within the deposition area, but do not result in detectable water quality problems in the water column.

Case Study - Petersburg

Several seafood processing plants are located at Petersburg, Alaska, a small community on the northern tip of Mitkof Island in southeastern Alaska. The processors are located along the waterfront and discharge processing wastes into Wrangell Narrows. This channel receives significant flushing due to the strong tidal currents and narrow channel cross-section. The major seafoods processed at these plants are salmon, halibut, shrimp, and crab.

Beyer et al. (1971) determined the effects of salmon processing wastes on the water quality and marine organisms near the Petersburg canneries. Water quality parameters observed included: dissolved oxygen (DO), temperature, salinity, turbidity, pH, and biochemical oxygen demand (BOD). Biological samples were collected and analyzed for species composition.

The only significant impact identified by this study was a limited area of waste accumulation and a resulting decline in the number of benthic organisms beneath the waste piles. DO, temperature, salinity, and pH values of the water column were not affected by the wastes. Turbidity and BOD were found to increase within a small area around the discharges, but soon dissipated after discharge was halted. Benthic organisms tended to avoid the waste piles but numerous scavengers (fish and birds) actively consumed wastes from the discharge plumes. The study concluded that strong tidal currents (up to 5 knots) flush the receiving area, limiting waste accumulation and benthic impacts to small areas near discharges. No deterioration of water quality conditions resulted from the waste discharge; daily and seasonal fluctuations in water quality parameters were due to tidal movement, sunlight intensity, and seasonal weather conditions.

Comparison with Akutan

The major difference between the Petersburg and Akutan processing areas is the vigorous flushing of the receiving waters off Petersburg. The Wrangell Narrows is an aptly named channel about 40 km long, 0.4 to 0.8 km wide, and 9 to 15 m deep at Petersburg. The tidal amplitude reaches 6 m, and maximum tidal current velocities range from 3 to 5 knots. The receiving waters at Akutan do not receive comparable flushing. The calculated residence time of the harbor is probably measured in weeks; however, turbidity and dissolved oxygen levels were not affected during the nondischarging condition of the investigation. With this feature in mind two conclusions are possible: 1) The high BOD and turbidity measurements observed at Petersburg during processing will most likely also be observed at Akutan during processing; and 2) the Petersburg study has shown that even with significant dispersion and flushing, some benthic impacts can result from seafood processing waste disposal.

Case Study - Kodiak

Kodiak Island has a large concentration of seafood processing plants that discharged wastes into Kodiak Harbor and Gibson Cove. Salmon and crab are the major seafoods processed, along with shrimp, clam, halibut, and herring. Approximately 38 million pounds of finished seafood products were processed by these plants in 1971. This corresponds to a waste discharge of approximately 72 million pounds (EPA 1975). This compares to a waste discharge of approximately 62 million pounds of codfish wastes alone from the Trident Seafood facility (based on full production of 500,000 raw pounds/day, 15 days/month, 31 percent production recovery).

EPA conducted two water quality surveys in the Kodiak area: one prior to waste treatment requirements in 1971, and the other after installation of screens in 1974.

The 1971 survey concluded that severe water quality and benthic impacts resulted from the waste discharge. Impacts included depressed DO concentrations, low light transmittance, waste accumulations, generation of hydrogen sulfide bubbles, elimination of benthic fauna, and extensive discoloration of the water column. Furthermore, water column stratification in the fall caused dissolved and suspended constituents of the low-density waste discharge to concentrate in the upper reaches of the water column. This exerted a large BOD loading and significantly lowered the surface water DO concentration, while the bottom water layer remained fairly well oxygenated. The sediments were anoxic due to the decomposition of the larger waste particles that settled out after discharge.

The 1974 survey was performed to evaluate the benefits of the new screening and solids removal equipment on water quality and benthic communities. Improvements included higher DO concentrations, reduction in hydrogen sulfide levels and bubble formation, some presence of pollution-tolerant polychaete worms, significant reduction in the quantity of settled wastes, and improved water color. Depressed DO concentrations in the surface layer were still evident during water column stratification, but to a lesser degree.

Comparison with Akutan

Kodiak Harbor, like Akutan, receives very little freshwater flow, which results in a marine rather than estuarine environment. Comparison between the harbors' physical and waste characteristics leads to the following:

1. Similar low energy flushing mechanisms indicate that minimal waste dispersion is likely to occur in Akutan Harbor.
2. The water column could be impacted during discharge. Water quality problems are less likely when water circulation in the inner harbor is induced by sustained winds from the east.

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Appendix A

CHRONOLOGICAL REPORTS OF FIELD STUDIES IN AKUTAN HARBOR, JUNE AND SEPTEMBER

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JONES & STOKES ASSOCIATES, INC. / 2321 P STREET / SACRAMENTO, CA. 95816 916/444-5638

DATE: June 13, 1983

TO: Bill Riley

FROM: Curtis Spencer

SUBJECT: Field studies in Akutan Harbor

This memo provides a nontechnical chronology of the June 1983 field work in Akutan Harbor. It documents the contacts made, general field work accomplished, and logistics problems encountered.

From May 31 to June 7 the project team traveled to Akutan and conducted field studies in support of Work Assignment 009, Akutan Harbor water quality assessment. The work was successfully completed, but not without difficulty.

The project team included the following:

Curtis Spencer, JSA*	Project Manager
Harvey Van Veldhuizen, JSA*	Cruise Leader, Task Leader (Biology)
Alice Godbey, JSA*	Field Technician
Gary Bigham, TTI**	Task Leader (Physical and Chemical Oceanography)
Mike Williamson, W&A***	Task Manager (Sidescan Sonar)
John Yearsley, EPA	
Dianne Soderlund, EPA	
Kim Sundberg, Alaska DFG	Task Manager (Video)

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* Jones & Stokes Associates, Inc.
** Tetra Tech, Inc.
*** Williamson & Associates

The logistics of shipping equipment to Dutch Harbor was an early concern prior to departure of the team. Equipment was shipped on May 26 on recommendation of Alaska Airlines to ensure delivery by June 1. On Monday, May 30, Gary Bigham was assured by Alaska Airlines that all shipments had arrived in Dutch Harbor. Gary communicated this news to Harvey Van Veldhuizen on the same day.

Tuesday, May 31, Curtis Spencer flew to Anchorage. The remaining Jones & Stokes Associates and Tetra Tech team members flew from Seattle on June 1, and all eight team members assembled at the Anchorage Airport and flew to Dutch Harbor.

Our checked luggage was retrieved and transported to the Fishing Vessel (F/V) Silver Sea, our 117-foot fish tender chartered for the Akutan Harbor survey. We reviewed the terms of the charter agreement with Konrad Engeset, part owner and captain of the F/V Silver Sea, and both parties signed the agreement shortly after noon on June 1.

Several team members returned to the airport to claim equipment and discovered that not all equipment had arrived. The missing equipment included the mini-ranger and 6 cases containing sidescan sonar gear. The shipment of sidescan sonar gear from Seattle had consisted of 9 pieces. Only 3 pieces arrived, along with the paperwork. (Mike Williamson was later told that the shipment had been split in Cordova, with only the lighter equipment and the paperwork going on to Anchorage and Dutch Harbor at that time. Apparently the heavier equipment was subsequently sent to Anchorage and then, we speculate, held for arrival of the other 3 pieces and the paperwork. Since these had already gone ahead, the freight just sat until discovered by Mike Williamson's associate.)

In addition, some equipment that had arrived was stored under lock and key and was not immediately obtainable by the crew since the holder of the key could not be located. It was therefore necessary to postpone our departure from Dutch Harbor until these problems could be resolved.

Numerous conversations ensued with Air Pac, Reeve Aleutian Airlines and Alaska Airlines, each of whom handled shipments. No satisfactory responses were obtained. In the evening Mike Williamson and Gary Bigham dispatched personnel to the Anchorage and Seattle air freight terminals. In Anchorage, Mike Williamson's associate was assured that the freight was not there, that it had been sent on to Dutch Harbor. Upon insisting, he was allowed to walk through the freight storage area.. He located the lost freight in the "dead freight" area, even though it was properly labeled. The mini-ranger was located at Reeve in Anchorage.

About 10:00 p.m. on June 1, the holder of the key to the storage facility came aboard the Silver Sea to arrange for transfer of the stored equipment. It was agreed to meet the following morning at 10:00 a.m. to retrieve the equipment.

On June 2, Mike Williamson's associate returned to the Anchorage air freight offices, saw to it the Reeve shipment (mini-ranger) made it on the plane to Cold Bay for transfer to Dutch Harbor. At Alaska Airlines/Air Pac he learned that the equipment did not get on the morning flight due to passenger luggage. He tentatively arranged a charter with Air Logistics to transfer the equipment to Dutch Harbor, and called Marion Adams, ADEC in Dutch Harbor, to advise us of the problem. Marion was out and a message was left on his answering machine.

In the meantime, the Air Pac and Reeve flights arrived, with no gear on either flight. The Reeve shipment had reportedly been bumped for passenger luggage in Cold Bay.

The team returned to the boat and were met by Marion Adams who advised of the phone message. Calls were placed to Anchorage to verify equipment status and a charter was authorized by Jones & Stokes Associates and contracted by Tetra Tech at $800 per hour air time to convey equipment from Anchorage and Cold Bay to Dutch Harbor. The authorization was granted about 4:00 p.m. on June 2. The plane was in the air within the hour. The gear arrived in Dutch Harbor at 9:45 p.m., and the Silver Sea departed for Akutan at about 11:00 p.m., as soon as the gear was aboard. We arrived in Akutan Bay about 4:00 a.m. and dropped anchor near the head of the bay.

Friday, June 3, we installed the two shore stations for the mini-ranger and the tide gage and tide staff. Approval for installations on existing docks was obtained from Trident Seafoods. Dianne and I spoke with Nils Dragoy, Manager of the Trident plant, and arranged to return for a tour and discussions later in the trip. The sidescan sonar and depth profiling equipment was then set up.

It was discovered that a short existed in a sidescan cable connector. A shorter cable was tried, but it was not of sufficient length.

Mike Williamson telephoned Seattle and Anchorage in the afternoon and arranged to obtain a new cable. In order to assure delivery, he had it sent freight to Anchorage and then arranged to have it carried as passenger luggage by a courier from Anchorage to Akutan.

In the meantime, Kim Sundberg of ADFG deployed the video camera at the Trident waste pile and obtained unrecorded video information on 3 transects (annotated as to observations and coordinates; the video recorder was inoperative). During retrieval of the camera the video image was lost. Diagnosis and repair required most of the evening and part of the next morning. The cause of the problem was a xener diode in the 28 VDC power supply for the video camera. It was decided to bypass the power supply by using two of the car batteries, obtaining about 26 VDC.

Dianne and I visited the village of Akutan and met with the mayor, Jacob Stepetin. We discussed beneficial uses of the harbor and its waters. These uses include:

- Swimming from the beach and dock in the summer.
- Local boat transportation.
- Harvest for subsistence of two types of clams (butter and steamer) from several beaches on the harbor.
- Subsistence harvest of salmon, trout and crab (when available). Trout and salmon are dried and salted.
- Duck hunting for food.
- Subsistence hunting for fur seals and sea lions.
- Harvest of cod for subsistence

Jacob indicated that cod had been infested with worms in recent years, and local use of it had nearly ceased. The project team verified this with hook and line techniques. No products are purchased from Trident or other local processors.

We discussed the City's application for ocean dumping and the EIS that may be required by EPA. The role of Jones & Stokes Associates in sampling was explained. Jacob indicated that the City desires to obtain an incinerator and possibly also service the solid waste (not processing waste) of the processors. The processors currently burn on the beach. (Burning at Trident and the beach near the Deep Sea was observed by the project team.) Jacob expressed a preference not to be involved in the collection and disposal of processing wastes.

We then visited the Western Sea, docked adjacent to the village. They indicated a processing season of only 50 days operation (king crab only) in Akutan from July 1, 1982 to date. They were packing and tying down equipment for a move up the chain to process salmon. Craig Cross, Alaska operations manager for the owners of the Western Sea and the Akutan, stated that the Western Sea would probably return to tie up in Akutan in subsequent years, but would not operate (80 percent probability) due to the status of the crab fishery. He indicated that prior owners had discharged waste next to the ship, but that since they have owned the ship (1978) that they have followed their permit, requiring discharge through a flexible outfall. Craig said we could find an old sludgy waste pile near the boat but very little evidence of any deposits at their outfall.

The team rechecked the tide gage for proper operation and set some buoys to mark current stations. That evening Mike Williamson worked further with electronic gear, especially the video camera. On Saturday morning, June 4, Mike had been successful in getting the camera to operate for short periods, but had detected a fault of some sort in the underwater portion that caused fuses to blow. Substituting higher value fuses only lengthened the time between fuse failures, and the camera was abandoned as unusable. No recorded photographic images were obtained.

On Saturday, June 4, the team began taking sediment samples and made salinity, temperature density, and secchi disk observations at 19 preselected sites in the inner and outer harbor. Sediment samples were successfully obtained at 18 of the 19 sites. The last site, near the Akun Strait, was determined to be rocky. In the meantime, the Air Pac goose arrived at Akutan at midday with the courier and new sidescan cable. After lunch Mike Williamson assembled the sidescan, and about 4:00 p.m., upon completion of the benthic sampling, began using the sidescan with the 100 kHz fish through the Akun Strait. We continued surveys with the 100 kHz fish, and completed one run from the head of Akutan Harbor to the Strait. We then attached the 500 kHz fish and surveyed the Trident and Western Sea discharge locations. Logs were kept of points on the survey lines using the mini-ranger and the ship's radar. An extensive record of bottom conditions was obtained.

Additional current meter buoys were set, the batteries were changed at one mini-ranger transponder, and buoy locations were logged for reference.

Sunday, June 5, the project team reviewed sidescan sonar records and selected locations for additional sediment samples. Eight benthic samples were taken at the Trident discharge site. The end of the Trident outfall is marked by a buoy, and a sample taken with the Van Veen grab at this location appeared to be 100 percent cod waste, most foul and objectionable, and which degassed and oozed out of the grab when brought to the surface. No samples were kept at this station. Trident pumps were operated intermittently through the outfall, and a white ring appeared on the water surface at one time; the team assumed that this surfacing coincided with pumping and that it represented surfaces of the discharge plume.

While the Silver Sea deployed drogues at Trident, the skiff was deployed with the sidescan gear and two team members surveyed the Corps of Engineers' small boat harbor site. The Silver Sea deployed drogues at Trident to determine nearshore current. (The easterly wind appeared to be a dominant influence here.) Deeper drogues were deployed across the harbor east of the village, and were monitored during the day. The sidescan and subbottom profiler were used later in the afternoon to survey the site of the Western Sea (which had pulled out from the dock in the morning) and at Trident. Two sediment samples were obtained at the old piles at the City of Akutan dock.

Dianne and I visited the Deep Sea, one of the two remaining processors in Akutan Bay as of today. We sought to meet with the plant manager, Merle Knapp. We were unsuccessful, but did meet Terry, the plant engineer. He showed us the head end of the processing, and indicated they process crab exclusively, are running 20-24 hours per day, and grind and discharge over the side. We arranged to meet with Merle the next morning.

The subbottom profiler was again deployed and old piles near the head of the bay were profiled. Two sediment samples were obtained at these old piles.

The small stream entering the head of the bay was gaged and the transponders checked. The last drogues were retrieved at 11:00 p.m.

Monday, June 6, the project team began water quality sampling and continued drogue studies as a substitute for the current meter, which had a malfunctioning directional indicator. Current meter readings were also taken; the wind conditions in the harbor were such that the boat swung back and forth at anchor so much that a 50 percent variation in velocity was observed. Attempts to use the current meter were terminated.

Dianne and I again visited the Deep Sea, moored at the head of the harbor. Dianne explored their permit status, and we were given a tour of the crab processing line. Floating crab waste, including occasional whole crabs and body shells, were observed floating next to the vessel. Merle Knapp, the current superintendent, indicated a willingness to provide input to Jones & Stokes Associates on the evaluation of waste disposal options through their Seattle office. He also expressed an interest on bidding on providing charter craft for future scientific work.

In the afternoon, Dianne, Harvey and I toured the Trident plant. The plant had been processing crab, but was shut down for most of the day for cleaning. Processing was set to resume the following morning. Nils Dragoy, the plant superintendent, discussed disposal options with us. He felt the economics of a waste conversion plant would not be favorable, and would provide no return on invested capital. He felt a 150-200 ton per day system would never pay. He noted that soy meal is a very competitive product in the same market as fish meal. He did provide us with an article, written in Norwegian, that discussed a different type of bioreduction, involving a composting or fermentation process, blending with herring, and use as animal feed.

Barging seemed less objectionable to him, and we discussed some specific engineering aspects relative to their plant. Nils indicated that the barge would occupy valuable dock space. The engineer believed a screw conveyor could be used to carry solids from the existing sump to the barge; they were unsure whether the existing utility corridor would accommodate the conveyor.

Three team members investigated a collection of discarded 50 gallon drums, some full of unidentified liquids, located at the head of the harbor. The villagers reported that the drums had been there at least 5-10 years, and had been put there by the processors. Signs of oil were visible on the beach.

Dianne and I attended the village Planning Commission meeting that evening. Nancy Gross, who serves as City Administrator and manages the City of Akutan office in Anchorage, led the meeting. Three village residents (Commission members) and Michael Cushing, a representative of the Alaska Department of Community Affairs, also were present.

Dianne and I explained the water quality and sediment work we were doing in the harbor, the environmental assessment that would follow, and the forthcoming EIS on the solid waste ocean dumping permit for the City. Community concerns seem to center on oil spills. These have historically been bad at the head of the bay. Sources were believed to be fishing boats and processors pumping their bilges. The worst time of year is reported to be the fall when processing activities are greatest. Villagers have previously contacted the Coast Guard on oil spill problems.

The village is also concerned about the Alaska Shell, a currently unoccupied processing ship moored at the old whaling station. The City is concerned about the oil that would be released should the ship break up or sink. The Alaska Shell reportedly goes aground in the winter on occasion, and, one Commission member speculated, may already be "sunk," resting on the bottom near shore. The village contacted the owners of the vessel last year and were told the ship was seaworthy, and were given a copy of a marine survey indicating about 0.25 inch of plate remaining.

Michael Cushing stated that his agency was conducting socioeconomic studies related to fisheries, and that be would be making a full presentation to the City Council on June 7. Other items on the Commission agenda were also discussed. It was indicated that the gage located on the stream at the head of the harbor was installed a year or two ago by Paradovich and Nottingham to estimate water availability for a long-term seafood processing development proposed by the City in this area.

Following the meeting the Silver Sea retrieved drogues, removed mini-ranger shore stations and, at about 10:00 p.m., departed Akutan Harbor for Dutch Harbor. Team members packed equipment and prepared to transfer gear in Dutch Harbor the next morning.

The Silver Sea captain arranged for transfer of our equipment to the air freight facility of Air Pacific, and later for transfer of team members, baggage and frozen sediment samples to the airport. At the airport it was arranged to sell six of the car batteries to Harding Lawson Associates to power mini-ranger equipment at Akutan for an expanded seaplane base. The team departed from Dutch Harbor on two separate flights.

Upon arrival in Anchorage, we retrieved three boxes of frozen sediment samples and five boxes of water quality samples that had been checked as excess baggage. I delivered them to Chemical and Geological Laboratories of Alaska, Inc., 5633 B Street, for processing. The samples were delivered intact with documentation of the chain of custody.

Other team members departed for home; I departed from Anchorage early June 8.

My overall assessment of the field program is that it was successful in spite of difficult logistics problems. The greatest disappointment was the lack of any recorded video images. Secondary to this was the malfunction of the current meter, and lack of effluent samples during cod processing (only crab was being processed by the two operating processors). The sidescan sonar was fully successful, sediment samples were carefully selected to represent the broadest range of harbor conditions possible, water quality samples were obtained throughout the harbor, and drogue studies were conducted at three locations for many hours.

Major limitations involve the limited processing activity at present, limited long-term current measurements (obtainable only by recording strings), and the fact that weather conditions in June provide little basis for evaluating fall and winter conditions, when processing activity tends to peak. Water stratification is likely to be maximum in the fall, and may influence the discharge plume and dissolved oxygen at depth.

Should further field effort be expanded it should consist of water quality sampling at the same stations used in this program, taken well into a period of heavy processing. Current meter arrays could also be deployed under varying tide and wind conditions, should further information on harbor circulation be desired. (The team believes wind and wave influences to be significant.)

If market conditions change such that processing activities return to levels of 1980 and 1981, the above program would become substantially more important to EPA in developing permit conditions. If the village plan for development of a world-class seafood processing complex at the head of the harbor ever materializes, additional analysis will be required.

JONES & STOKES ASSOCIATES, INC. / 2321 P STREET / SACRAMENTO, CA. 95816 *916/444-5638*

September 23, 1983

TO: Curt Spencer

FROM: Harvey Van Veldhuizen

RE: September Field Work for EPA Akutan WA 9/WA 11

Harvey Van Veldhuizen and Alice Godbey of Jones & Stokes Associates met Gary Bigham and Gary Voerman at Seattle-Tacoma International Airport on Thursday, September 15, at 0700 for departure for Anchorage. Lee Rogers, Alaska Department of Fish and Game, joined us at the Anchorage Airport. Lee assisted us as we obtained our freight from the air cargo terminals in Anchorage. We also picked up a few supplies from hardware and grocery stores near the airport.

While we waited for Tom Dillard to arrive from Los Angeles, I met with Dr. Jerry Kudenov and we discussed the data we had collected in June. After Tom Dillard arrived, we departed for Dutch Harbor at 1300 hours in a Twin Otter aircraft chartered from Sea Airmotive, Anchorage, Alaska. It was obvious at that time that a smaller aircraft would have been inadequate because of the bulk of three of the pieces of equipment.

At Dutch Harbor, we met Larry Reed, skipper of the F/V Karin Lynn. Larry informed me that Rick Hastings, partner-owner of the F/V Karin Lynn, had just left, and that Merle Knapp of the M/V Deep Sea would sign the charter contract. We loaded our equipment aboard the F/V Karin Lynn, picked up the Van Veen grab, and purchased 10 auto batteries. After dinner at the Unisea Inn, we departed Dutch Harbor at 2200 hours. Members of the scientific party included: Alice Godbey and me; Gary Bigham and Tom Dillard from Tetra Tech; Lee Rogers from ADFG; and Gary Voerman from EPA. Jacob Stepetin, Mayor of Akutan, was a crew member on the F/V Karin Lynn.

On Friday, 16 September, we established four shore stations for the miniranger system. This took most of the morning because of the effort required to set up the two stations near the mouth of Akutan Harbor. The rest of the day was spent occupying water quality stations until 2200 hours. We launched one drogue at 2100 hours, and left one water quality station for the next day because of poor visibility. Anchored vessels in the harbor blocked out all but one miniranger channel at this station, and fog and darkness prevented visual location of the station relative to shore features.

On Saturday, 17 September, we occuppied the last water quality station, and began sediment sampling for Work Assignment 11. We chose to occupy these stations first because of concerns for weather conditions. Winds from the east-southeast were at 20 knots, gusting to 30 knots, resulting in 4-6 foot chop. Although these were not ideal conditions for operating the Van Veen grab, they were perhaps the best that could be expected for the time of year. Between sediment sampling, we deployed additional drogues and recorded positions of drogues released earlier. By 2130 hours, we had occupied all sediment sampling stations.

On Sunday, 18 September, we awoke to calm seas. We seized the opportunity to conduct camera work in the outer harbor stations. We were disappointed to find that the still camera was not operating properly. In transit and between stations, we located and took miniranger readings on the drogues. We also took water quality data at the optional station for Work Assignment 11. At 1300 hours, we occupied a third sediment station in the inner harbor, near Sediment Station 6 occupied in June. This additional station was occupied because of the discussion I had with Dr. Kudenov. He believe there is good evidence that a plume may occur to the southwest of the Trident wastepile, which has adversely impacted the benthos in this area. After sampling at this location, we continued camera work on and near the Trident wastepile. Biological sorting was also conducted on sediment samples collected the previous day.

At 1800 hours, we had completed all work required by the scope of work with the exception of camera work at the Akutan City Dock. At that point, Gary Voerman and I discussed our next move. We had arranged a meeting with the Akutan City Council for 2000 hours that evening. We also decided that the two outer shore stations could not be removed after dark because of dangerous conditions involving landing a skiff on a rocky shore at one station and the need to hike along a narrow ridge surrounded by steep cliffs at the other station.

We decided to occupy the optional sediment sampling station and the last camera station while Gary and I attended the City Council meeting, removing the shore stations in the morning, and leaving for Dutch Harbor mid-day on Monday. I attended the City Council meeting with Gary Voerman and Jacob Stepetin (Mayor of Akutan and crew member of the F/V Karin Lynn). The ship returned from the sampling shortly after we finished the meeting with the City Council. We occupied the last camera station at the Akutan dock, and watched the video tapes after tying up to the M/V Deep Sea that evening at 2200 hours.

On Monday morning, 19 September, we checked the position of and recovered all drogues. We removed the shore stations by

1200 hours. We waited at the M/V Deep Sea for an hour while people and equipment were loaded on board for transport to Dutch Harbor. During this period, we completed biological sorting and prepared for departure. We arrived at Dutch Harbor at 1900 hours, and spent the night at the Unisea Inn. Our charter technically ended at 1900 hours, and bunk space on board F/V Karin Lynn had been turned over to M/V Deep Sea personnel travelling with us to Dutch Harbor. On Tuesday morning, we offloaded our equipment from the F/V Karin Lynn by 0930. We returned the Van Veen grab and disposed of the batteries. We spent the rest of Tuesday at the Dutch Harbor terminal, waiting for flights to arrive. The fog lifted enough by late afternoon that we could all depart from Dutch Harbor. At Anchorage, Tom Dillard caught a flight to Los Angeles, and Gary Bigham, Alice, Gary Voerman, and I caught flights to Seattle that got us in around 0630 on Wednesday, September 21.

I would like to make three observations regarding the trip as a whole. First, it was a pleasure to have Jacob Stepetin, Mayor of Akutan, as a crew member. We made every effort to have him participate in various phases of the work effort. We discussed with him some of the creatures found and how the information would be used in our report. This participation should assist EPA's effort to explain to the Akutan community the work that has been conducted on the two work assignments.

Second, I would like to note that the boat and her crew were satisfactory. Larry Reed was a good skipper and was able to hold position in rough waters at a level that permitted us to carry out our work. The weather, more than anything else, prevented us from obtaining replicate samples in a tight sampling pattern. The degree of precision will not be completely apparent until we have had time to plot station locations.

Finally, we should note that the work was very successful. A wealth of data was obtained, including drogues studies in excess of work scope requirements. The difficultires were few, and are listed below:

- We noted discrepancies between DO as measured by the water quality probe and by the Winkler titration method. Changing the sensor membrane on the DO probe did not eliminate these discrepancies. As a result, we collected data using both techniques. We are in the process of checking out this discrepancy.

- We discovered that the pH probe would not read properly when inserted into undisturbed sediment in the Van Veen grab. Since the initial goal was to measure pH in undisturbed samples in the field, we opted for the fallback position, which was to have the lab analyze it at $4/sample. It was not until the last day of sampling that we realized that the probe was malfunctioning because of interference from the metal grab. If we would have realized this earlier, we could have measured pH in a subsample taken from the grab.

- The first two drogues that we deployed sank. The total number of drogues deployed was therefore 24 rather than 26. However, tracking occurred for much longer that the 20-hour time period called for in the scope of work.
- The ADFG still camera did not operate properly and was not deployed. We tested it before attaching it to the sled, and discovered that the film advance mechanism was inoperative. The video camera worked well. The live picture on the monitor was clear. When we watched it later on taped replay, we noted regular, infrequent bursts of static. These may be in the film or in the playback device.
- No processors were discharging during our final day in Akutan (Monday, 19 September), therefore we could not collect effluent samples. If we had collected samples, we could not have gotten them to a lab for 48 hours, twice the preferred maximum of 24 hours.

Appendix B

ANALYTIC MODEL OF HARBOR FLUSHING USING JUNE DROGUE DATA

The following describes the analytical solution used to calculate residence time based on June drogue data.

The simplified governing equation is:

$$g \frac{\partial \eta}{\partial x} = \frac{\partial}{\partial z} \left(N_v \frac{\partial u}{\partial z}\right) \qquad \text{Eq. 1}$$

where:

g = gravitational acceleration
η = surface level term
x = horizontal directional component along channel longitudinal axis
z = vertical directional component
N_v = vertical eddy viscosity coefficient
u = horizontal velocity in x-direction

Assumptions:

1. Flow is assumed to occur only in x-direction along main axis of channel (no lateral flow)

2. Coriolis forces are ignored (reasonable for small areas)

3. Convective accelerations are ignored

4. Steady-state conditions exist

5. Water density and atmospheric pressure are homogeneous

6. N_v is assumed constant over the water column.

Boundary conditions for Equation 1 are:

$$\tau_{sx} = -\rho_s N_v \frac{\partial u}{\partial z} \qquad @\ z = 0 \text{ (surface)} \qquad \text{Eq. 2}$$

$$u = 0 \qquad @\ z = H \text{ (bottom)} \qquad \text{Eq. 3}$$

where:

ρ_s = density of water at surface
H = total water depth
τ_{sx} = surface wind shear stress = $\rho_s K \cos\Theta |W| W$
W = wind velocity
Θ = angle between W and the x-axis (positive counterclockwise)
K = drag coefficient;
= $0.4 \times 10^{-6}\ W^{1/2}$ for $W < 31$ mph
= 3.1×10^{-6} for $W \geq 31$ mph

Integrating Equation 1 twice and using the boundary conditions (Equations 2 and 3), Equation 1 yields:

$$u = \frac{g}{N_v}\frac{\partial n}{\partial x}\left\{\frac{(H-z)^2}{2} - H(H-z)\right\} + \frac{\tau_{sx}}{\rho_s N_v}(H-z) \qquad \text{Eq. 4}$$

Equation 4 contains two unknowns, u and σ z . To evaluate , use can be made of the fact that no net flux will occur in the channel, or:

$$\int_0^H u \, dz = 0 \qquad \text{Eq. 5}$$

Integrating Equation 4 over the water depth and setting the integral to zero yields:

$$0 = \frac{g}{N_v}\frac{\partial n}{\partial x}\int_0^H\left\{\frac{1}{2}(H-z)^2 - H(H-z)\right\}dz + \frac{\tau_{sx}}{\rho_s N_v}\int_0^H (H-z)\,dz \qquad \text{Eq. 6}$$

Evaluation of the integrals in Equation 6 and some algebraic manipulation yields:

$$\frac{\partial n}{\partial x} = \frac{3}{2}\frac{\tau_{sx}}{\rho_s H g} \qquad \text{Eq. 7}$$

Substitution of Equation 7 into Equation 4 produces an equation which can be used to solve for u explicitly:

$$u = \frac{\tau_{sx}(H-z)}{4\rho_s N_v}\left(1-3\frac{z}{H}\right) \qquad \text{Eq. 8}$$

Appendix C

MODEL OF HARBOR FLUSHING USING SEPTEMBER SALINITY DATA

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The flushing time of a pollutant, as determined by the fraction of freshwater method is

$$T_f = \frac{V_f}{R} \qquad \text{Eq. 9}$$

where

V_f = volume of freshwater in the estuary

T_f = flushing time of a pollutant which enters the head of the estuary with the river flow

Equation 9 is equivalent to the following concept of flushing time and is more intuitively meaningful:

$$T_f = \frac{M}{\dot{M}} \qquad \text{Eq. 10}$$

where

M = total mass of conservative pollutant contained in the estuary

$\dot{M}$ = rate of pollutant entry into the head of the estuary with the river water

Since the volume of freshwater in the estuary is the product of the fraction of freshwater (f) and the total volume of water (V), Equation 9 becomes:

$$T_f = \frac{f V}{R} \qquad \text{Eq. 11}$$

If the estuary is divided into segments the flushing time becomes:

$$T_f = \Sigma \frac{f_i V_i}{R_i} \qquad \text{Eq. 12}$$

Equation 12 is more general and accurate than the three previous expressions because both f_i (the fraction of freshwater in the ith segment) and R_i (the freshwater discharge through the ith segment) can vary over distance within the estuary. Note that the flushing time of a pollutant discharged from some location other than the head of the estuary can be computed by summing contributions over the segments seaward of the discharge.

A limitation of the fraction of freshwater method is that it assumes uniform salinity throughout each segment. A second limitation is that it assumes during each tidal cycle a volume of water equal to the river discharge moves into a given estuarine segment from the adjacent upstream segment, and that an equal volume of the water originally in the segment moves on to the adjacent one downstream. Once this exchange has taken place, the water within each segment is assumed to be instantaneously and completely mixed and to again become a homogeneous water mass. Proper selection of estuarine segments can reduce these errors.

Calculation of flushing time by the fraction of freshwater method requires a six-step procedure:

1. Graph the estuarine salinity profiles.

2. Divide the estuary into segments. There is no minimum or maximum number of segments required, nor must all segments be of the same length. The divisions should be selected so that mean segment salinity is relatively constant over the full length of the segment. Thus, stretches of steep salinity gradient will have short segments and stretches where salinity remains constant may have very long segments.

3. Calculate each segment's fraction of fresh water by:

$$f_i = \frac{S_s - S_i}{S_s} \qquad \text{Eq. 13}$$

where

f_i = fraction of fresh water for segment "i"

S_s = salinity of local sea water, o/oo

and

S_i = mean salinity for segment "i", o/oo

4. Calculate the quantity of fresh water in each segment by:

$$W_i = f_i \times V_i \qquad \text{Eq. 14}$$

where

W_i = quantity of fresh water in segment "i"

and

V_i = total volume of segment "i" at MTL

5. Calculate the exchange time (flushing time) for each segment by:

$$T_i = W_i/R \qquad \text{Eq. 15}$$

where

T_i = segment flushing time, in tidal cycles

and

R = river discharge over one tidal cycle

6. Calculate the entire estuary flushing time by summing the exchange times for the individual segments:

$$T_f = \sum_{i=1}^{n} T_i \qquad \text{Eq. 16}$$

where

T_f = estuary flushing time, in tidal cycles

n = number of segments.

Table C-1 shows the flushing time calculated for each segment (Figure 11), assuming boundary seawater salinity (S_s) of 31.6 ppt, and a total freshwater input (R) of 64 cfs (1.81 m^3/sec or 8.1 x 10^4 m^3/cycle). The estimated residence time is approximately 177 days (342 tidal cycles).

Table C-1. Calculation of Flushing Time by Segmented Fraction of Freshwater Method

Segment Number	Mean Segment Salinity S_i(ppt)	Mean Segment Length (m)	Mean Segment Cross-sectional Area (m^2)	Segment Mean Tide Volume V_i (m^3)	Fraction of River Water $f_i = \frac{Ss-Si}{Ss}$	River Water Volume $W_i = f_i x V_i$ (m^3)	Segment Flushing Time * $T_i = W_i/R$ (tidal cycles)
1	29.50	1000	2.78×10^4	2.78×10^7	.0665	1.85×10^6	22.8
2	29.95	1000	3.66×10^4	3.66×10^7	.0522	1.90×10^6	23.5
3	30.10	1000	4.75×10^4	4.75×10^7	.0475	2.27×10^6	28.0
4	29.55	1000	7.61×10^4	7.61×10^7	.0649	4.94×10^6	61.0
5	29.50	1000	11.0×10^4	11.00×10^7	.0665	7.30×10^6	90.1
6	30.30	1400	16.4×10^4	16.40×10^7	.0411	9.47×10^6	116.9
						$\sum_{i=1}^{n} T_i =$	342.3 cycles 177.1 (days)

Up Estuary →

* R = 64 cfs

Appendix D

SEPTEMBER WATER QUALITY PARAMETERS

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Table D-1. Parameter Values at September Water Quality Stations.

STATION	DEPTH (Meters)	TEMPERATURE (Degrees C)	SALINITY (PPT)	DENSITY (Sigma t)	pH
1	0	8.2	29.10	22.65	8.3
	5	8.2	29.32	22.82	8.3
	10	8.2	29.33	22.83	8.3
	15	8.2	29.33	22.83	8.3
	19	8.2	NA	NA	8.3
2	0	8.2	28.94	22.53	8.3
	5	8.2	29.08	22.63	8.3
	10	8.2	29.22	22.74	8.3
	15	8.2	29.39	22.88	8.3
	20	8.2	29.46	22.93	8.3
	26	8.2	29.56	23.01	8.4
3	0	8.2	30.15	23.47	8.3
	5	8.2	30.38	23.65	8.3
	10	8.2	NA	NA	8.3
	15	8.2	30.52	23.76	8.3
	20	8.1	30.54	23.79	8.3
	25	8.2	30.56	23.81	8.3
	30	8.2	30.75	23.95	8.3
4	0	8.2	28.85	22.45	8.3
	5	8.2	28.90	22.49	8.3
	10	8.2	28.97	22.55	8.3
	15	8.1	28.98	22.57	8.3
	20	8.2	29.02	22.60	8.3
	25	8.2	29.07	22.64	8.3
	30	8.2	29.10	22.66	8.3
	35	8.2	29.10	22.66	8.3
5	0	8.2	30.16	23.49	8.3
	5	8.2	30.10	23.45	8.3
	15	8.2	30.28	23.59	8.3
	20	8.2	30.10	23.45	8.3
	35	8.2	29.89	23.28	8.3
	44	8.2	NA	NA	8.3
6	0	8.2	NA	NA	8.3
	5	8.2	NA	NA	8.3
	15	8.2	NA	NA	8.3
	24	8.1	NA	NA	8.3
	39	8.0	NA	NA	8.3
7	0	8.2	29.74	23.15	8.3

Table D-1 Continued

STATION	DEPTH (Meters)	TEMPERATURE (Degrees C)	SALINITY (PPT)	DENSITY (Sigma t)	pH
	5	8.2	29.87	23.25	8.3
	10	8.2	NA	NA	8.3
	15	8.1	29.89	23.28	8.3
	20	8.1	30.13	23.47	8.3
	30	8.1	30.15	23.48	8.3
	35	8.1	30.16	23.49	8.3
8	0	8.2	30.62	23.84	8.3
	5	8.2	30.64	23.85	8.3
	10	8.2	30.66	23.87	8.3
	15	8.2	30.68	23.88	8.3
	20	8.1	30.68	23.88	8.3
	25	8.1	30.71	23.92	8.3
	30	8.1	30.72	23.93	8.3
	35	8.0	30.75	23.97	8.2
9	0	8.3	30.20	23.50	8.3
	6	8.3	30.37	23.63	8.3
10	0	8.2	NA	NA	8.3
	5	8.2	30.76	23.95	8.3
	10	8.2	NA	NA	8.3
	15	8.2	30.85	24.02	8.3
	20	8.2	30.76	23.95	8.3
	25	8.2	31.07	24.19	8.3
11	0	8.0	29.27	22.81	8.3
	5	8.0	29.24	22.79	8.3
	10	8.0	29.24	22.79	8.3
	20	8.0	29.25	22.79	8.3
	37	8.0	29.32	22.85	8.3
	44	7.9	29.32	22.86	8.3
12	0	8.0	29.22	22.77	8.2
	6	7.9	29.22	22.77	8.2
	12	7.9	29.18	22.75	8.2
	20	7.9	29.21	22.78	8.2
	28	7.9	29.25	22.81	8.2
	34	7.9	29.25	22.81	8.2
	37	7.9	NA	NA	8.1
13	0	8.3	28.70	22.32	8.3
	5	8.3	29.73	22.35	8.3
	12	8.2	29.77	22.39	8.3

Table D-1 Continued

STATION	DEPTH (Meters)	TEMPERATURE (Degrees C)	SALINITY (PPT)	DENSITY (Sigma t)	pH
	21	8.1	29.93	22.53	8.3
	35	8.1	29.01	22.59	8.3
14	0	8.3	30.35	23.75	8.3
	5	8.3	30.59	23.80	8.3
	10	8.3	30.68	23.87	8.3
	15	8.2	30.67	23.88	8.3
	20	8.2	30.48	23.73	8.3
	25	8.1	29.57	23.03	8.4
15	0	8.1	29.18	22.72	8.3
	5	8.1	29.47	22.95	8.3
	10	8.1	29.52	22.99	8.3
	14	8.1	NA	NA	8.3
16	0	8.1	29.47	22.95	8.3
	5	8.1	29.79	23.20	8.3
	10	8.1	30.33	23.63	8.3
	15	8.1	30.52	23.77	8.3
	20	8.1	30.75	23.95	8.3
	30	8.1	30.93	24.09	8.3
	35	8.1	31.20	24.31	8.3
	40	8.0	31.28	24.38	8.3
	50	7.8	31.30	24.43	8.3
	55	7.7	31.06	24.25	8.3
17	0	8.0	30.83	24.03	8.3
	5	8.0	30.87	24.06	8.3
	10	8.0	30.92	24.10	8.3
	15	8.0	30.94	24.12	8.3
	20	8.0	30.96	24.14	8.3
	25	7.9	30.98	24.16	8.3
	30	7.9	30.81	24.03	8.3
	35	7.9	NA	NA	8.3
18	0	8.1	31.51	24.54	8.3
	5	8.1	31.52	24.55	8.3
	10	8.1	31.53	24.56	8.3
	15	8.1	31.53	24.56	8.3
	20	8.1	31.55	24.58	8.3
	25	8.1	31.64	24.66	8.3
	30	8.1	31.61	24.63	8.3
	35	8.0	31.61	24.64	8.3
	40	8.0	31.63	24.66	8.3

Table D-1 Continued

STATION	DEPTH (Meters)	TEMPERATURE (Degrees C)	SALINITY (PPT)	DENSITY (Sigma t)	pH
	45	7.9	31.65	24.69	8.3
	50	7.8	31.63	24.68	8.3
	55	7.8	31.67	24.71	8.3
19	0	8.0	31.49	24.55	8.3
	5	8.0	31.49	24.55	8.3
	10	8.0	31.52	24.57	8.3
	15	8.0	31.55	24.60	8.3
	20	8.0	31.57	24.61	8.3
	25	7.9	31.59	24.64	8.3
	30	7.8	31.63	24.68	8.3
	35	7.8	31.62	24.68	8.3
20	0	8.2	31.23	24.31	8.3
	5	8.0	31.35	24.44	8.3
	15	7.9	31.43	24.51	8.3
	20	7.8	31.56	24.63	8.3
	25	7.4	31.77	24.85	8.2
	30	7.4	31.66	24.76	8.2
	35	7.3	31.74	24.84	8.2
	40	7.1	31.79	24.91	8.2
	45	7.0	31.79	24.92	8.2
	50	7.0	31.83	24.95	8.2
	60	7.0	31.86	24.97	8.2
	70	6.6	32.08	25.20	8.2

Appendix E

JUNE WATER QUALITY PARAMETERS MEASURED AT WATER QUALITY STATIONS

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Table E-1. Parameter Values-at Water Quality Station No. 1

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.41	0.39	0.35	0.50
D.O., mg/l	--	--	--	9.17
H_2S, mg/l	<.002	<.002	<.002	<.002
Oil & grease, mg/l	--	--	--	--
NH_3-N, mg/l	0.11	0.12	0.12	0.10
TKN, mg/l	--	--	--	--
NO_3-N, mg/l	--	--	--	--
NO_2-N, mg/l	--	--	--	--

---

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 111 ft = 33.8 m

Table E-2. Parameter Values at Water Quality Station No. 2

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.40	0.35	0.33	0.85
D.O., mg/l	--	--	--	--
H_2S, mg/l	<.002	<.002	<.002	<.002**
Oil & grease, mg/l	--	--	--	--
NH_3-N, mg/l	0.08	0.10	0.19	0.09**
TKN, mg/l	--	--	--	--
NO_3-N, mg/l	--	--	--	--
NO_2-N, mg/l	--	--	--	--

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* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 140 ft = 42.7 m
** taken at 130 ft = 39.6 m

Table E-3. Parameter Values at Water Quality Station No. 3

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.42	0.31	0.40	0.87
D.O., mg/l	--	--	--	9.43
H_2S, mg/l	<.002	<.002	<.002	<.002
Oil & grease, mg/l	--	--	--	0.01
NH_3-N, mg/l	0.07	0.05	0.07	<0.05
TKN, mg/l	--	--	0.11	0.05
NO_3-N, mg/l	--	--	0.19	0.40
NO_2-N, mg/l	--	--	<0.010	<0.010

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 120 ft = 36.6 m

Table E-4. Parameter Values at Water Quality Station No. 4

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.44	0.54	0.38	0.34
D.O., mg/l	--	--	--	9.72
H_2S, mg/l	<.002	<.002	<.002	<.002
Oil & grease, mg/l	--	--	--	0.06
NH_3-N, mg/l	0.20	0.10	<0.05	0.06
TKN, mg/l	--	--	--	0.15
NO_3-N, mg/l	--	--	--	0.58
NO_2-N, mg/l	--	--	--	<0.010

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 95 ft = 29.0 m

Table E-5. Parameter Values at Water Quality Station No. 5

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.42	0.30	0.42	0.50
D.O., mg/l	--	--	--	9.60
H_2S, mg/l	<.002	<.002	<.002	<.002
Oil & grease, mg/l	--	--	--	0.02
NH_3-N, mg/l	0.06	0.08	0.08	0.09
TKN, mg/l	--	--	--	0.14
NO_3-N, mg/l	--	--	--	0.55
NO_2-N, mg/l	--	--	--	<0.010

---

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 125 ft = 38.1 m

Table E-6. Parameter Values at Water Quality Station No. 6

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.55	0.39	0.34	0.62
D.O., mg/l	--	--	--	9.51
H_2S, mg/l	<.002	<.002	<.002	<.002
Oil & grease, mg/l	--	--	--	<0.01
NH_3-N, mg/l	0.05	<0.05	<0.05	0.19
TKN, mg/l	--	--	--	0.23
NO_3-N, mg/l	--	--	--	0.26
NO_2-N, mg/l	--	--	--	<0.010

---

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 130 ft = 39.6 m

Table E-7. Parameter Values at Water Quality Station No. 7

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.44	0.39	--	--
D.O., mg/l	--	10.00	--	--
H_2S, mg/l	<.002	--	--	<.002
Oil & grease, mg/l	--	<0.01	--	--
NH_3-N, mg/l	<0.05	--	--	<0.05
TKN, mg/l	--	--	--	0.11
NO_3-N, mg/l	--	--	--	<0.10
NO_2-N, mg/l	--	--	--	<0.010

---

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 60 ft = 18.3 m

Table E-8. Parameter Values at Water Quality Station No. 8

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.44	0.35	0.35	0.94**
D.O., mg/l	--	--	--	9.58**
H_2S, mg/l	--	--	--	<.002
Oil & grease, mg/l	--	--	--	--
NH_3-N, mg/l	<0.05	<0.05	<0.05	0.06
TKN, mg/l	<0.05	<0.05	<0.05	0.06
NO_3-N, mg/l	<0.10	<0.10	0.11	0.34
NO_2-N, mg/l	0.014	0.012	0.015	<0.013

---

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 160 ft = 48.8 m
** taken at 155 ft = 47.2 m

Table E-9. Parameter Values at Water Quality Station No. 9

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.74	0.65	0.36	0.42**
D.O., mg/l	--	--	--	10.00**
H_2S, mg/l	--	--	--	<.002
Oil & grease, mg/l	--	--	--	--
NH_3-N, mg/l	0.05	0.12	<0.05	<0.05
TKN, mg/l	0.05	0.12	<0.05	--
NO_3-N, mg/l	<0.10	0.11	0.12	--
NO_2-N, mg/l	0.015	0.012	0.012	--

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 165 ft = 50.3 m
** taken at 160 ft = 48.8 m

Table E-10. Parameter Values at Water Quality Station No. 10

PARAMETER	SURFACE	50 ft*	70 ft*	BOTTOM*
Turbidity, NTU	0.59	0.40	0.31	0.65
D.O., mg/l	--	--	--	--
H_2S, mg/l	--	--	--	<.002
Oil & grease, mg/l	--	--	--	--
NH_3-N, mg/l	<0.05	<0.05	<0.05	<0.05
TKN, mg/l	<0.05	<0.05	0.08	--
NO_3-N, mg/l	0.17	<0.10	0.13	--
NO_2-N, mg/l	0.012	0.012	0.012	--

* 50 ft = 15.2 m; 70 ft = 21.3 m;
bottom depth = 180 ft = 54.9 m

Appendix F

SEPTEMBER SEDIMENT ANALYSIS

Table F-1. Sediment Analysis, September 1983, Station S1

PARAMETER	A	B	C	AVERAGE	RANGE	STANDARD DEVIATION
TOC %	1.7	1.5	1.2	1.47	1.2-1.7	0.25
Sulfide ppm	20	<10	30	20	<10-30	10
Ammonia ppm	17	10	17	14.7	10-17	4.0
Organic Nitrogen ppm	683	780	453	639	453-780	168
pH	7.3	7.4	7.5	7.4	7.3-7.5	0.1
Sand %	16.2	19.4	27.8	21.1	16.2-27.8	6.0
Silt %	75.6	72.7	65.1	71.1	65.1-75.6	5.4
Clay %	8.2	7.9	7.1	7.7	7.1-8.2	0.6

Table F-2. Sediment Analysis, September 1983, Station S2

PARAMETER	D	E	F	AVERAGE	RANGE	STANDARD DEVIATION
TOC %	1.1	0.59	1.4	1.03	0.59-1.4	0.4
Sulfide ppm	350	1800	-	1075	350-1800	1025
Ammonia ppm	10	53	17	27	10-53	23
Organic Nitrogen ppm	1190	1047	603	947	603-1190	306
pH	7.3	7.7	7.3	7.4	7.3-7.7	0.2
Sand %	47.2	51.7	32.4	43.8	32.4-51.7	10
Silt %	45.6	43.6	60.1	49.8	43.6-60.1	9
Clay %	7.2	4.7	7.5	6.5	4.7-7.5	1.5

Table F-3. Sediment Analysis, September 1983, Station S3

PARAMETER	G	H	J	AVERAGE	RANGE	STANDARD DEVIATION
TOC %	0.86	0.91	0.74	0.84	0.74-0.91	0.09
Sulfide ppm	20	40	30	30	20-40	10
Ammonia ppm	15	8	26	16	8-26	9.1
Organic Nitrogen ppm	555	332	344	410	332-555	125
pH	7.4	7.3	7.4	7.4	7.3-7.4	0.06
Sand %	62.3	59.4	65.9	62.5	59.4-65.9	3.3
Silt %	31.8	35.3	29.3	32.1	29.3-35.3	3.0
Clay %	5.9	5.3	4.8	5.3	4.8-5.9	0.6

Table F-4. Sediment Analysis, September 1984, Station S4

PARAMETER	K	L	M	N	P	AVERAGE	RANGE	STANDARD DEVIATION
TOC %	0.80	0.77	0.87	1.2	1.5	1.03	0.77-1.5	0.32
Sulfide ppm	30	<10	10	30	100	36	<10-100	37.1
Ammonia ppm	7	10	19	22	25	17	7-25	7.8
Organic nitrogen ppm	393	90	381	958	685	501	90-958	331
pH	7.4	7.4	7.5	7.4	7.4	7.4	7.4-7.5	0.05
Sand %	65.2	75.1	65.9	43.8	42.7	58.5	42.7-75.1	14.5
Silt %	28.8	20.8	28.9	47.3	48.4	34.8	20.8-48.4	12.3
Clay %	6.0	4.1	5.2	8.9	8.9	6.6	4.1-8.9	2.2

Table F-5. Sediment Analysis, September 1984, Station S5

PARAMETER	Q	R	S	T	U	AVERAGE	RANGE	STANDARD DEVIATION
TOC %	0.56	0.82	0.43	0.57	0.57	0.59	0.43-0.82	0.14
pH	7.3	7.4	7.4	7.5	7.6	7.4	7.3-7.6	0.1
Sand %	79.6	79.3	84.4	75.4	78.6	79.5	75.4-79.6	3.2
Silt %	16.1	16.6	11.6	20.1	17.1	16.3	11.6-20.1	3.1
Clay %	4.3	4.1	4.0	4.5	4.3	4.2	4.0-4.5	0.2

Table F-6. Sediment Analysis, September 1984, Station S6

PARAMETER	V	W	X	Y	Z	AVERAGE	RANGE	STANDARD DEVIATION
TOC %	1.1	0.69	0.61	0.73	0.90	.81	0.61-1.1	0.2
pH	7.8	7.6	7.6	7.4	7.6	7.6	7.4-7.8	0.14
Sand %	78.7	80.4	89.9	79.9	82.9	82.4	78.7-89.9	4.5
Silt %	18.1	16.3	6.7	16.6	13.7	14.3	6.7-18.1	4.5
Clay %	3.2	3.3	3.4	3.5	3.4	3.4	3.2-3.5	0.1

Appendix G

SPECIES LIST FOR "BACKGROUND" STATIONS IN JUNE

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Appendix G

Species list for "background" stations in June, rare species (i.e., those found only once at one station) are listed in Appendix I.

Taxon	Station																
	1	2	3	5	6	7	8	9	10	11	12	16	14	13	15	17	18
Polychaeta																	
Eunoe nr. *oerstedi*	3											2	1		1		1
Pholoe nr. *parva*	1	2	1				2		1								
Eteone cf. *californica*						1										1	1
Phyllodoce groenlandica			2						1				4				
Ceratonereis cf. *paucidentata*			1			1											
Nereis nr. *zonata*	2								2			1					
Nephtys ferruginea	1		1													1	1
Nephtys sp.										1				1		1	
Glycera capitata		2							1		1						
Glycinde picta										1	2	3	1	1	2	.2	
Goniada maculata																	2
Nothria elegans												1					2
Ninoe simpla	6	11	10	2		4	12	2	6	1	4	6		6	5	3	7
Leitoscoloplos elongata	1	1					1					2		1			1
Boccardia nr. *polybranchia*	44	78	38	31	38	32	42	26	50	45	49	17	68	2	3	4	2
Laonice cirrata		1	11						1		1	3					1
Prionospio cirrifera						1		3						7	1	2	
Prionospio steenstrupi		3	1			1	4	3	3	9	6	2		1	1	2	3
Spio cirrifera											2	1					
Magelona longicornis									1			1			3		
Chaetozone setosa							1				1						
Scalibregma inflatum	6	2		15		3	9	3		1		5		1			1
Notomastus nr. *lineatus*									2	1	1				1	1	7
Mediomastus nr. *capensis*				4		2				1	1	1			1		1
Travisia forbesii											4						8
Euclymene reticulata		3				3			1	2	2	2	6			5	3
Maldane glebiflex									4			1					
Praxillella gracilis			1					2			3	2					3
Myriochele heeri																1	2
Amphicteis glabra	1						2	1	2			2			1		1
Amphisamytha bioculata	1	1							1	1	1	1					5
Asabellides sibirica	1											1					
Terebellides stroemi											4	1				1	
Polycirrus nr. sp. III													2			1	
Jasmineira pacifica								1								2	1
Nemertea																	
Cerebratulus sp.						1									1		
Nemertean spp.						1	1	1			1				1		
Echiura																	
Echiuris echiuris	3																
Gastropoda																	
Margarites sp.								1			1						1
Turbinella sp.							1									1	
Oenopota sp.			1						1							1	
Retusa sp.									1				1				
Bivalvia																	
Nucula tenuis						1	2	1		2							
Nuculana radiata		1		1	1				2		3	1			2		2
Axinopsida orbiculata	1	9	4			3			4	7	1	1			1	1	9
Macoma calcarea	1															1	
Macoma elimulata								1			2						
Macoma moesta	12	13	4		2	20	7	1	6	2	2	2		4	8	2	7
Macoma sp.									1				2				
Tellina sp.													2				
Mya pseudoarenaria			1						1								
Crustacea																	
Ostracoda		1							1								
Amphipoda													5				2
Crangon communis										1				1			
Chionoecetes bairdi	1			1			1					1					
Pinnixa sp.					2		1										
Ophiuroidea																	
Amphiodia sp.	1												1		1		
Echinoidea																	
Echinarachnius parma													10				
Vertebrata																	
Lumpenus maculatus							1				1						

Appendix H

SPECIES LIST FOR STATIONS ON OR NEAR WASTEPILES IN JUNE

Appendix H

Species list for stations on or near waste piles in June. Rare species (i.e., those found only once at one station) not found at background stations are listed in Appendix I.

Taxon	Station												
	19B	20	21	22	24	26	27	28	29	30	31	32	4
Polychaeta													
Eunoe nr. *oerstedi*									4	1	1		1
Pholoe nr. *parva*			2					1	3			7	1
Phyllodoce groenlandica								1					
Exogone gemmifera									2				
Nephtys ferruginea												1	
Nephtys sp.													1
Glycera capitata			2							3	3		
Glycinde picta										1			
Ninoe simpla			8			3		6		1			8
? *Meiodorvillea* sp.	1										1		
Leitoscoloplos elongata											1	1	
Boccardia nr. *polybranchia*	42		35			55		22	247	41	69	169	21
Laonice cirrata			1										
Polydora socialis													1
Prionospio cirrifera								1			1		
Prionospio steenstrupi			4					14	16	8	32	3	2
Spio cirrifera								2					
Spiophanes bombyx											2		
? Trochochaetidae n.g.								3					
Chaetozone setosa											1		
Scalibregma inflatum			41							1		2	14
Capitella sp. A			1									2	
Notomastus nr. *lineatus*													1
Euclymene reticulata													1
Amphicteis glabra												1	1
Amphisamytha bioculata													1
Asabellides sibirica			1										
Euchone nr. *analis*											2		
Nematoda									2				
Nemertea													
Cerebratulus sp.													1
Nemertea spp.	2							1					1
Echiura													
Echiuris echiuris						C			A	C	P	A	
Bivalvia													
Nucula tenuis				2	1				1	1			
Nuculana radiata			1										1
Axinopsida orbiculata			1	6			1			1	1	1	3
Diplodonta sp.									1				1
Macoma calcarea			2										
Macoma moesta			10							1	1		4
Macoma sp.			1						1			1	
Mya pseudoarenaria												1	
Hiatella sp.											1		
Crustacea													
Cumacea	P								3				
Mysidacea		P											
Amphipoda									6			1	
Crangon communis			1										
Chionoecetes bairdi												1	
Hyas lyratus								1				2	
Ophiuroidea													
Amphiodia sp.			1										

P: Present
C: Common
A: Abundant

Appendix I

RARE SPECIES IN JUNE

Appendix I . Rare species, i.e. one individual found only at one station in June.

Background Stations

Station	Species	Group
Station 1	*Hyas lyratus*	(crab)*
Station 2	*Capitella* sp. A	(polychaete)*
	Diplodonta sp.	(bivalve)*
Station 3	*Polydora socialis*	(polychaete)*
	Clinocardium sp.	(bivalve)
Station 5	*Piromis* sp.	(polychaete)
Station 7	Harmothoinae n.g.	(polychaete)
	Sipunculida	(sipunculid)
Station 10	cf *Neonotomastus* sp. A	(polychaete)
	Neptunea sp.	(gastropod)
	Macoma carlottensis	(bivalve)
Station 12	? Trochochaetidae n.g.	(polychaete)*
Station 14	*Neverita* sp.	(gastropod)
	Cumacea	(crustacean)*
	Mysidacea	(crustacean)*
Station 17	*Hiatella* sp.	(bivalve)
Station 18	*Nicolea* nr. *zostricola*	(polychaete)

Stations on or near Wastepiles **

Station	Species	Group
Station 19B	*Platynereis bicanaliculata*	(polychaete)
Station 21	*Artacama conifera*	(polychaete)
Station 27	*Nuculana minuta*	(bivalve)
Station 29	*Auchenoplax* cf. *crinita*	(polychaete)
	Modiolus sp.	(mussel)
Station 30	*Lumbrineris* nr. *similabirs*	(polychaete)
Station 31	*Cirratulus cirratus*	(polychaete)
	Armandia brevis	(polychaete)
	Sabellidae sp.	(polychaete)
	Yoldia hyperborea	(bivalve)

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* Found once at background stations, but also found on or near wastepiles (see Appendix H).

* Not found at background stations.

Appendix J

SPECIES LIST FOR INNER HARBOR STATIONS IN SEPTEMBER

SPECIES LIST FOR INNER HARBOR STATIONS IN SEPTEMBER. RARE SPECIES (i.e. THOSE FOUND ONLY ONCE IN ONE SAMPLE FROM THE INNER HARBOR) ARE LISTED IN APPENDIX L.

	STATION S1			STATION S2			STATION S3		
TAXON	A	B	C	D	E	F	G	H	J
Polychaeta									
Eunoe nr *oerstedi*	1				1		1		1
Pholoe nr *parva*		3					1	2	1
Eteone nr *californica*	1	1			1				1
Nereis nr *zonata*		2	1	1		4	3	2	1
Glycera capitata				1			1	1	
Glycinde picta	1								1
Lumbrineris nr *similabris*									2
Ninoe simpla	14	8	9	2		2	15	11	13
Leitoscoloplos elongata		2							1
Boccardia nr *polybranchia*	13	4	4	10			33	9	8
Polydora socialis									2
Prionospio steenstrupi	4	23	4	1					7
Spio cirrifera	1		3					1	2
Capitella sp. A			2		34				
Mediomastus nr *capensis*		1		2				5	1
Scalibregma inflatum	5		7	4	1	4	3	2	13
Armandia brevis	4	1	1						
Euclymene reticulata								4	1
Praxillella gracilis							1	5	1
Amphicteis glabra	1						3		3
Amphisamytha bioculata							1		1
Nemertea spp.	2							1	
Nematoda		1	1						
Gastropoda									
Retusa sp.						1		2	
Bivalvia									
Nucula tenuis	1			1			1		
Nuculana radiata	2	1						2	
Axinopsida orbiculata	10	2	4	1	2	2	2	7	6
Macoma moesta	12	17	1	4	2		7	1	1
Macoma obliqua		3						1	
Macoma carlottensis		1					1	1	
Macoma calcarea	1			1					

Appendix K

SPECIES LIST FOR OUTER HARBOR AND AKUTAN BAY STATIONS IN SEPTEMBER

SPECIES LIST FOR OUTER HARBOR

AND AKUTAN BAY STATIONS IN SEPTEMBER

RARE SPECIES (I.E. THOSE FOUND ONLY ONCE IN ONE SAMPLE FROM THE OUTER

HARBOR OR AKUTAN BAY) ARE LISTED IN APPENDIX L

	STATION S4					STATION S5					STATION S6				
	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z
Polychaeta															
Eunoe nr *oerstedi*	1				1	1	1		1	2					
Pholoe nr *parva*			2		1					1	1				
Anaitides nr *citrina*		4	1				1	1							
Eteone nr *californica*									2			1			
Phyllodoce groenlandica											1			1	
Exogone lourei								1	1	1	1				
Streptosyllis nr *latipalpa*		1										1		1	1
Sphaerodoropsis minuta			2												
Glycera capitata									1		1	1		1	
Glycinde picta		1	2	1	2		2			1		2			1
Nephtys nr *californiensis*	1												1		
Nephtys ferruginea			1					1						1	
Nephtys punctata					1	1									
Nothria elegans						1	2			2	2	1	1	2	1
Lumbrineris nr *similabris*						1						2			2
Ninoe simpla	9	11	3	4	6	2	3	4	7	4		5		1	
Leitoscoloplos elongata	2	1	1	1	2	1	1	1	1			2	1		1
Tauberia gracilis		1		1				1			1		2	2	
Boccardia nr *polybranchia*	1		2	1											
Laonice cirrata		1				1						1			
Prionospio steenstrupi		3	13	2	10	2	7	6	3	25	1		6		1
Spiophanes bombyx		3						1						1	
Apistobranchus tullbergi													2		
Cossura nr *soyeri*	1			2	6							1			
Magelona longicornis	1		1			1									
Chaetozone setosa			2		5									1	
Capitella sp. A			5	1			1			4			3	1	1
Decamastus nr *gracilis*			2	1		1	1	2		3	1	1	1		1
Notomastus lineatus		3			2	3	4	3	4	2	1	2	2	5	
Mediomastus nr *capensis*	1	14	7	1	1	5	2	20		13		3	2	7	8
Scalibregma inflatum		1	1		2		1	1	2	1	2	3		1	
Armandia brevis												1			1
Travisia forbesii	1	4	1			2	3	2	2		1	2	1		3
Ophelina acuminata	1								1	4				1	
Myriochele nr *heeri*		3			2					1					
Euclymene reticulata	1		1	3	1	3	1	2	2	2		3		1	2
Praxillella gracilis	1	1		2		1				1					
Rhodine bitorquata		1						5		1					
Amphicteis glabra	1			1	1					2		1	3	2	3
Asabellides sibirica	2	3				1	1	1		3					
Amphisamytha bioculata		1	2	1				2	1			1		3	1
Terebellides stroemi				1	4				1	1	2	3	1	3	1
Amaeana occidentalis										1				1	
Pista crinita	1	1							1	1		1			
Chone nr *mollis*	1	5			1				1	1	4	2	3	2	1
Euchone hancocki										9		1	3	3	3
Fabricinae spp.												4	2		

	STATION S4					STATION S5					STATION S6				
	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z
Foraminifera spp.	2	3		5	4		2			1					
Pennatularia															
Virgulariidae											3		1	1	1
Nematoda	6	36	39		7	4	14	25	23	87		21	29	36	18
Nemertea spp.	1	3			1	1	3	4						2	1
Sipunculida	1		1											1	1
Gastropoda															
Margarites sp.			1				1	1		3	1			1	1
Oenopota sp.		1					1		1	1	1	1	1	1	1
Unidentified spp.				1			2	3							1
Bivalvia															
Nucula tenuis		1		1	4	2			3	3				1	
Nuculana radiata	3	2	1	1	1		4	2	1	2	6	1	6	1	2
Axinopsida orbiculata	3	3		4	9	10	11	10	5	22	1	7	3	7	
Diplodonta sp.						1									
Macoma moesta	6	4	7	9	17	7	2	12	4	11	3	6	5	5	7
Macoma sp.							2			1					
Cyclocardia sp.								1		1			2		
Clinocardium sp.										2			1	1	
Siliqua sp.								1						1	
Mya pseudoarenaria		1			1					1		1			
Cryptomya sp.		1				1		1		1					
Crustacea															
Ostracoda												3	1		
Harpinia kobjakovae						1	7	3	4	5		1	6	2	3
Ampelisca eschrichi									1	2					1
Chionoecetes bairdi				2											
Ophiuroidea															
Amphiodia rossica						1							1	4	
Echinoidea															
Echinarachnius parma							2		4	1	1				
Holothuroidea															
Cucumaria calcigera						1		2	1	1		1			1
Synaptidae					1			1							
Ascidia															
Stolidobranchiata sp.					1	1								1	1

Appendix L

RARE SPECIES, I.E. ONE INDIVIDUAL FOUND ONLY AT ONE STATION, IN SEPTEMBER

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RARE SPECIES, I.E. ONE INDIVIDUAL FOUND ONLY AT ONE STATION, IN SEPTEMBER

Inner Harbor Stations

tion S1

A	*Anaitides* nr *citrina*	(polychaete)**
	Cossura nr *soyeri*	(polychaete)**
	Chionocetes bairdi	(crab)* (**)
	Amphiodia rossica	(ophiuroid) **
	Notomastus lineatus	(polychaete) **
	Terebellides stroemi	(polychaete) **
	Turcica sp.	(gastropod)
	Axiothella rubrocincta	(polychaete) **
	Priapulis caudatus	(priapulid) **
	Cerebratulus sp.	(nemertean)

ion S2

Margarites sp.	(gastropod) **
Cryptomya sp.	(bivalve) **
Echiuris echiuris	(echiuran)
Turbonilla sp.	(gastropod) **
Diplodonta sp.	(bivalve) **

n S3

Chone nr *mollis*	(polychaete) **
Oenopota sp.	(gastropod) **
ya pseudoarenaria	(bivalve) **
ephtys ferruginea	(polychaete) **
ephtys nr *califoriensis*	(polychaete) **
haetozone setosa	(polychaete) **
sabellides sibinica	(polychaete) **

Outer Harbor Stations

Station S4

K	*Priapulus caudatus*	(priapulid) **
	Turbonilla sp.	(gastropod) **
L	*Adontorhina* sp.	(gastropod)
M	*Nereis* nr *zonata*	(polychaete) **
	Prionspio cirrefera	(polychaete)
	Ampelisca macrorephala	(amphipod)
N	*Spio cirrifera*	(polychaete) **
P	*Lumpenus maculatus*	(fish)*
	Arcidae?	(bivalve)
	Molpadidae?	(holothuroid)
Q	*Chaetepterus variopedatus*	(polychaete)
	Melinna elisabethae	(polychaete)
R	*Syllis* sp.	(polychaete)
	Scolelepis squamata	(polychaete)
	Retusa sp.	(gastropod) **
S	*Asychis similis*	(polychaete)
	Holothuroidea	(sea cucumber)
T	*Harmothoinae* sp.	(polychaete)
	Axiothella rubrocincta	(polychaete) **
U	*Sphaerodoropsis sphaerulifer*	(polychaete)
V	Pterobranch hemichordate	
X	*Panomya arctica*	(bivalve)
Y	Sphaerodoridae n.g.	(polychaete)
	Macoma carlottensis	(bivalve) **
	Hydrozoa	(hydroid)
	Ascidia	(tunicate)

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* Rare in sample, but common based on underwater video camera observations

** Also found in inner or outer harbor stations